DANA
EIP

MODEL 451

Microwave Pulse Counter

Operating & Service Manual

SECTION

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MODEL 451

Microwave Pulse Counter

Operating & Service Manual

Serial Prefix/CCN Group beginning: 1001

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SECTION 1

GENERAL INFORMATION & SPECIFICATIONS

1-1. DESCRIPTION

1-2. The EIP Model 451 Microwave Pulse Counter automatically and directly measures the frequency of pulse modulated microwave signals between 300 MHz - 18 GHz. Pulse widths can be as narrow as 100 nanoseconds, with no minimum or maximum pulse repetition frequency limits.

1-3. The 451 also measures the frequency of CW microwave signals, and carrier signals with FM modulation up to 40 MHz peak-to-peak deviation at 10 MHz modulation rates. No manual switching is required to measure CW or pulsed frequencies — the counter will automatically measure either type of signal. Sensitivity is -10 dBm to 10 GHz; -5 dBm to 18 GHz. A built-in limiter provides overload protection of up to 1 watt peak from 925 MHz - 18 GHz.

1-4. All front panel controls except **SAMPLE RATE** are externally programmable. One input to the counter (**Band B**) accepts signals over the range of 925 MHz - 18 GHz. Option P2 provides a second input (**Band A**) to cover the range of 300 MHz - 950 MHz.

1-5. The display on the 451 Counter provides a direct readout of the measured frequency over the entire operating range of the counter with 10 kHz resolution. The counter also includes automatic suppression of leading zeros, except during a no signal input condition.

1-6. The frequency readout of the 451 is displayed in a fixed position format that is conveniently sectionalized in GHz and MHz. Gate time is fixed at 100 microseconds.

1-7. For applications where less resolution is required, pushbutton display blanking (**RESOLUTION**) is provided to simplify the readout.

1-8. To assure trouble-free performance, the 451 Pulse Counter is completely solid-state. For ease of repair and maintenance, the major portion of the counter circuitry is contained on plug-in printed circuit boards or in easily removed modules. Special test points allow monitoring of critical circuit functions.

1-9. INSTRUMENT IDENTIFICATION

1-10. The 451 Pulse Counter is identified by two number sets: the Model and Configuration Control Number (e.g: . 451-CCN1001), and a specific Serial Number (e.g: 12345). Both sets of numbers should be mentioned in any correspondence or parts orders relating to the counter.

1-11. SPECIFICATIONS

1-12. Model 451 Microwave Pulse Counter specifications are given in Table 1-1.

GENERAL SPECIFICATIONS

Frequency Range: Band A: Band B:	 300 MHz to 950 MHz (Option P2) 925 MHz to 18 GHz
Pulse Characteristics: Pulse width (measured at 3 dB points): Pulse repetition frequency:	 100 nsec min. Min. - 50 Hz normal, 0 Hz rear panel selected Max. - No limit (Note 1)
Accuracy: CW or pulses >100 μsec: Pulse <100 μsec: Averaging error (kHz rms): Gate error (max.):	 Time base accuracy ±1 count Time base accuracy ± averaging error ± gate error $\frac{100\text{ kHz}}{\sqrt{\text{P.W.}-.04}}$ (200 kHz: Band A) P.W. = pulse width (μsec) $\pm\ \frac{40\text{ kHz}}{\text{P.W.}-.04}$
Time Base:	Standard / Option P1
Oscillator Type:	Room Temperature Crystal / Temperature Compensated Crystal (TCXO)
Crystal frequency:	10 MHz
Stability: Aging rate: Temperature: (0-50°C)	 $<\lvert 3 \times 10^{-7}\rvert$ /mon. $<\lvert 3 \times 10^{-5}\rvert$ / $<\lvert 2 \times 10^{-6}\rvert$
Line voltage:	±10% change produces frequency shift $<\lvert 1 \times 10^{-7}\rvert$
Warm up time:	None required

Sensitivity: Band A (Opt. P2): Band B:	 300 to 950 MHz -10 dBm peak 925 MHz to 10 GHz -10 dBm peak 10 GHz to 18 GHz -5 dBm peak
FM Tolerance:	40 MHz peak-to-peak deviation worst case for modulation rates from DC to 10 MHz
Maximum Input Level (peak): Band A: 300 to 950 MHz (Opt. P2) Band B: 925 MHz to 18 GHz	Operating / Burnout Level +10 dBm / +27 dBm +10 dBm / +30 dBm
Input Impedance: Connector:	Band A (Opt. P2): 50 Ω nom., BNC / Band B: 50 Ω nom., Type N precision
Measurement Speed (Band B Only): Acquisition Time: PRF >100 Hz: PRF <100 Hz: Reading Time (Band B only)	 100 msec + 50 msec/GHz $100\text{ msec} + \frac{5}{\text{PRF}}$ sec/GHz $\frac{1}{\text{PRF}} \times \frac{100}{\text{P.W.}}$ sec PW = pulse width (μsec) PRF = pulse repetition frequency (Hz)
Display:	7 digit LED with fixed decimal point. Leading zero suppression.
Resolution:	10 kHz, 100 kHz, 1 MHz
Power:	100/120/220/240 VAC ±10%, 50-60 Hz, 100 watts

Note 1: 20 kHz max with Gate Modulation turned on.

GENERAL SPECS. CONT'D.

Operating Temperature:	0 to 50°C
Weight:	Net 25 lbs. Shipping 30 lbs.
Dimensions:	3.5" high and 16.75" wide and 19" deep
Accessories Furnished:	8 foot power cord and instruction manual
Accessories Available:	2010008 Rack Mounting Kit 5700001 Carrying Case Model 400 Delay Generator

TABLE 1-1. SPECIFICATIONS - 451 MICROWAVE PULSE COUNTER

FRONT PANEL:

Controls:	
Sample Rate/Hold:	Varies display reading time from 0.1 sec/reading to 10 sec/reading. "Hold" displays last reading.
Test-200 MHz:	Displays 200 MHz internal test frequency.
Display Test:	Tests all LED numeral segments.
Resolution:	(1 MHz, 100 kHz, 10 kHz): Sets display resolution.
Band Select (A or B):	Switch selects either Band A (Opt. P2) or Band B input.
Auto/Manual (Band B):	
Auto Mode:	Band B searches upward for input signal beginning 100 MHz above preset number.
Manual Mode:	Inhibits search. Signal must lie between 100 MHz and 325 MHz above preset number.
Thumbwheel Switch (Band B):	
Auto Mode:	Sets start point of frequency sweep (100 MHz above preset number.)
Manual Mode:	Sets operating frequency range (100 MHz to 325 MHz above preset number.)
Indicators:	
Level:	Indicates sufficient input level.
Lock:	Indicates signal acquired.
Gate:	Indicates measurement in process.
Remote:	Indicates Remote Programming (Option P4) active.
Reduce Signal (Band B):	Indicates excess signal level.
Connectors:	
Band A input:	Type BNC female - 300 to 950 MHz (Option P2)
Band B input:	Type N precision female - 925 MHz to 18 GHz

REAR PANEL:

Controls:	
Power input:	Power module containing AC connector, fuse, and voltage control for 100, 120, 220, or 240 VAC.
Storage (On/Off):	Normally on. In off position, display updates continuously during measurement cycle.
Gate Modulation: (On/Off)	Normally off. In on position, noise modulation is applied to eliminate errors due to synchronous signals.
Min. PRF = (50 Hz/0):	Normally in 50 Hz position. In 0 position, allows measurements of very low PRF signal.
Connectors:	
10 MHz reference output:	1 V peak-to-peak min. into 50 Ω
Gate Output:	-0.5v min. into 50 Ω corresponding to counter gate.
Signal Threshold Output:	-0.5v min. into 50 Ω corresponding to signal exceeding threshold.
Inhibit Input:	ECL high (-0.9v) inhibits. ECL low (-1.7v) enables. From 50 Ω source, 0 volts will inhibit, -1v will enable. Input impedance: 50 Ω to -2 volts.

OPTIONS:

P1:	TCXO - temperature compensated crystal oscillator
P2:	Band A: 300 - 950 MHz
P3:	Rear panel inputs: Band A and B
P4:	BCD output/remote programming Remote programming: provides rear panel programming of all front panel controls except SAMPLE RATE. Requires ground contact closure; one control line per function (T^2L and DTL compatible). Digital output: 7 data digits in parallel form. 1-2-4-8 "1" state positive.

TABLE 1-1 (Continued). SPECIFICATIONS - 451 MICROWAVE PULSE COUNTER

SECTION 2

INSTALLATION

2-1. UNPACKING

2-2. The EIP Model 451 Microwave Pulse Counter arrives ready for operation. Carefully inspect the shipping carton before opening for any evidence of visible or concealed damage. If any seems apparent, ask that the shipper's agent be present when the counter is unpacked.

2-3. Remove the packing carton and supports, being careful not to scar or damage the counter. Make a complete visual inspection of the counter, checking for any damage or missing components. Check that all switches and controls operate mechanically. Report any damage to EIP immediately.

2-4. INSTALLATION

2-5. There are no special installation instructions for the 451 Pulse Counter. The unit is a self-contained bench or rack mounted instrument, which only requires connection to a standard, single-phase, 110/120 or 220/240 volt, 50-60 Hz power line for operation. CAUTION: Check current rating of counter fuse and voltage range PC board in power module (on rear panel of counter), before applying power to the counter. Module PC board should show the correct nominal line voltage when installed in the module.

2-6. INCOMING OPERATIONAL CHECK

2-7. The following procedure outlines an operational check of the counter which may be conducted without special tools, signal generators, or test equipment. The internal Time Base Clock is used as the input signal to the Direct Counter, therefore it cannot check the operation of the Band A Prescaler or the Band B Converter.

a. Turn counter **POWER** switch off. Check fuse rating and card in power module (see paragraph 2-5).

b. Connect counter power cord to the voltage source specified in paragraph 2-5. The ground terminal on the power cord plug should connect to a reliable earth ground.

c. Press **POWER** switch (on front panel) to turn counter on. The counter display should light, and the internal cooling fan should operate.

d. Partially depress either of the two **RESOLUTION** switches and release it, so neither switch remains in the depressed position. All digits in the display should indicate "0" (zero).

e. Depress the front panel **200 MHz TEST** switch. The display should indicate "200.00" (200 MHz). Note that the two leading zeros are blanked (not lit).

f. Blank the 10 kHz digit by pressing the right hand **RESOLUTION** switch.

g. Depress the **200 MHz TEST** button again. The display should indicate "200.0".

h. Test both **RESOLUTION** switches. Note that the digit immediately above the switch, and any digit to the right will be blanked.

i. Unblank all display digits (see "d" above).

j. With no input signal, the entire display should show all zeros in both positions of the **BAND** switch.

k. Depress the **DISPLAY TEST** switch. All display digits should show "8" (all segments of each digit lighted).

l. This completes the counter operational check.

SECTION 3

OPERATION

> WARNING
>
> DO NOT APPLY A SIGNAL EXCEEDING THE MAXIMUM INPUT SPECIFICATION TO ANY INPUT. EXTENSIVE DAMAGE NOT COVERED BY THE WARRANTY WILL OCCUR, EVEN IF THE COUNTER IS TURNED OFF, OR APPEARS TO BE INOPERATIVE.

3-1. INTRODUCTION

3-2. The Model 451 Microwave Pulse Counter has three principle modes of operation: automatic, manual, and externally enabled. This section will describe each of these modes, and will provide information on timing considerations and instrument accuracy.

3-3. CONTROLS, INDICATORS AND CONNECTORS

3-4. Front panel controls, indicators and connectors are shown in Figure 3-1 and described in Table 3-1. Rear panel controls and connectors are shown in Figure 3-2 and described in Table 3-2.

3-5. NUMERICAL DISPLAY BRIGHTNESS ADJUSTMENT

3-6. Apparent brightness of the light-emitting-diode (LED) numerical display may be varied by adjustment of potentiometer A102R35. (R35 is located near the top front of PC Board A102, and is accessible by removing the top cover of the counter.) Adjust R35 clockwise to increase display brightness, or counter-clockwise to decrease the brightness.

3-7. OPERATION IN THE AUTOMATIC MODE

3-8. In this operational mode, either CW or pulse signals can be measured. Connect the input frequency to the appropriate input connector: **Band B** for frequencies between 925 MHz - 18 GHz, or **Band A** (Option P1) for frequencies between 300 MHz - 950 MHz. If the input signal level is sufficient for counting, the **LEVEL** indicator will light. If the proper band and input have been selected, the **LOCK** indicator will light. In Band B, if the input signal level is too high, the **REDUCE SIGNAL** indicator will light. Measurements will be made at a rate determined by the **SAMPLE RATE** control.

3-9. In Band B, acquisition speed may be improved by presetting the start frequency via the thumbwheel switch. The minimum frequency which can be acquired will then be 100 MHz above the switch setting.

CAUTION: An erroneous reading may result if an applied signal is less than 100 MHz above the switch setting.

3-10. OPERATION IN THE MANUAL MODE

3-11. Manual mode operation applies to Band B only, and is achieved by setting the **MANUAL SELECT/AUTO SWEEP** switch to the **MANUAL SELECT** position, and the thumbwheel switch to the proper frequency. In this mode, the operating frequency range is from 100 MHz to 325 MHz above the switch setting. Since no sweep is required, the acquisition time in this mode is virtually eliminated.

CAUTION: Application of signals which lie between 100 - 325 MHz below the switch setting may result in erroneous readings.

3-12. EXTERNALLY ENABLED OPERATION

3-13. The use of the rear panel **INPUT INHIBIT** makes possible a class of measurements known as *dynamic frequency measurements* — measurements made at a specified point in time on a signal whose frequency is some repetitive function of time. When a high level is applied, the 451 is inhibited from making a measurement. Thus a signal at the **INPUT INHIBIT** can be used as an enable signal to make a measurement at a desired time. The width of the enable signal determines the duration of the measurement — typically 40 nanoseconds less than the applied pulse.

3-14. INPUT INHIBIT REQUIREMENTS

3-15. The **INPUT INHIBIT** on the 451 is designed to be compatible with either a 50 ohm impedance pulse generator, or emitter-coupled-logic (ECL) devices. An internal termination of 50 ohms returned to -2 volts makes this dual compatibility possible. An ECL high level signal (-0.8 to -1.1 V) will inhibit measurement, while an ECL low level signal (-1.5 to -2.0 V) will enable measurement. ECL devices are designed to drive 50 ohm lines without reflections when the lines are terminated with 50 ohms returned to -2 V. The direct compatibility with a 50 ohm pulse generator results from the fact that zero volts from a 50 ohm source will produce -1 V at the **INPUT INHIBIT** (inhibiting the 451), while a -1 V signal into 50 ohms will produce -2 V at the **INPUT INHIBIT** thus enabling the 451.

3-16. PULSE PROFILE MEASUREMENTS

3-17. Automatic pulse measurements can determine the average frequency of a pulse. In some cases however, additional information may be necessary. For example, a pulsed magnetron may exhibit substantial frequency shift

(Continued on Page 3-4)

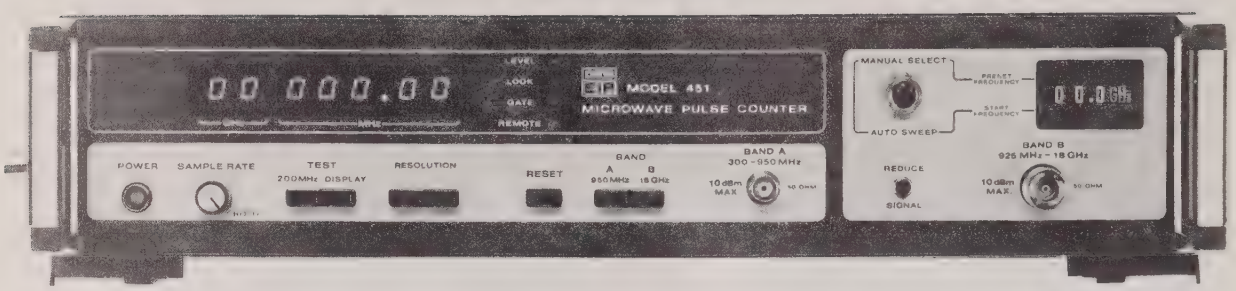


FIGURE 3-1. FRONT VIEW - 451 MICROWAVE PULSE COUNTER

TABLE 3-1. FRONT PANEL CONTROLS, INDICATORS AND CONNECTORS

POWER On/Off Switch

Turns counter power on and off.

SAMPLE RATE/HOLD Control

Continuously variable control for one-tenth to ten seconds per reading. (Required Gate time is added to sample time.) HOLD position retains reading until manually reset.

200 MHz TEST Switch

Provides check of internal counter circuits. Display should indicate "200.00" MHz.

DISPLAY TEST Switch

Displays "88 888.88" to test all LED segments.

RESOLUTION Switches

Provide blanking of either one or two least significant digits for resolution of 10 kHz, 100 kHz, or 1 MHz.

RESET Switch

Manually overrides the SAMPLE RATE/HOLD control, resets display to zero, and initiates a new reading.

BAND Select Switches

Select desired operating band — either BAND A (Option P2 - 300 MHz to 950 MHz), or BAND B (900 MHz to 18 GHz).

BAND A Connector

BNC female connector for Band A input (Option P2).

Visual Display

The 7-digit LED (light-emitting-diode) display provides a direct numerical readout of the input frequency. The display is sectionalized into GHz and MHz ranges.

LEVEL Indicator

When lit, indicates that input signal is of sufficient level for counting. Blinking light indicates that PRF (pulse repetition frequency) is too low.

LOCK Indicator

When lit, indicates that input signal has been acquired.

GATE Indicator

Indicates that counter is in measurement portion of its cycle.

REMOTE Indicator

Used with Option P4 (BCD/Remote Programming). When lit, indicates that Remote Enable has been activated, and that all front panel controls except SAMPLE RATE are disabled.

MANUAL SELECT/AUTO SWEEP Switch

Selects manual or automatic operation for Band B.

PRESET/START FREQUENCY Thumbwheel Switch

In the MANUAL mode, the switch sets the operating frequency range. The signal must lie between 100 MHz to 350 MHz above switch setting. In the AUTOMATIC mode, the switch sets the start of the search range. Input frequency must be at least 100 MHz above switch setting.

REDUCE SIGNAL Indicator

Indicates excessive signal input to Band B. WARNING: Signals in excess of rated specifications may cause extensive damage NOT covered by the warranty.

BAND B Connector

Type N precision connector for Band B operation.

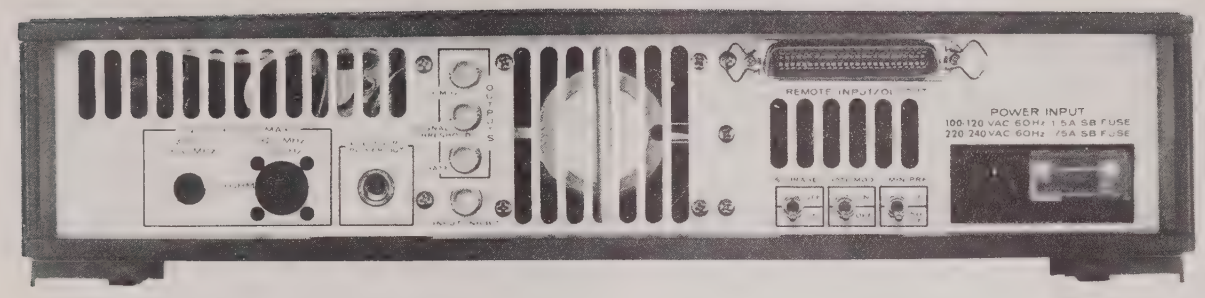


FIGURE 3-2. REAR VIEW - 451 MICROWAVE PULSE COUNTER

TABLE 3-2. REAR PANEL CONTROLS AND CONNECTORS

Rear Panel Inputs

(Option P3) Allows modification of counter for rear panel inputs.

ACCESSORY POWER OUT Connector

Provides power for 451 Pulse Counter accessories.

10 MHz OUTPUT Connector

Output of internal 10 MHz clock, 1 V p-p min into 50 ohms.

SIGNAL THRESHOLD OUTPUT Connector

Pulse output representing signal threshold level of input pulse. Typically occurs 20 nanoseconds after input pulse, and is used for frequency profile measurements.

GATE OUTPUT Connector

Provides Gate pulse representing actual time at which measurement is being made. Used in frequency profile measurement.

INPUT INHIBIT Connector

External pulse input for frequency profile measurements.

Remote Input/Output Connector

(Option P4) Connector for BCD/Remote Programming.

STORAGE Switch

Normally ON. In the OFF position, display updates continuously during measurement cycle.

GATE MOD Switch

Normally OFF. In the ON position, noise modulation is applied to eliminate errors due to synchronous signals.

MIN PRF Switch

Normally in 50 Hz position. In 0 position, allows measurement of very low PRF signal. NOTE: Reading will not automatically reset when signal is removed.

AC Power Module

Contains AC power line receptacle, fuse, and PC board for voltage selection.

near the leading and trailing edges of the pulse, or a pulsed Gunn diode oscillator may exhibit frequency shift during a pulse due to peak power thermal effects. Measurements of these characteristics are easily made with only the 451 and a delaying pulse generator (see Figure 3-3). The SIGNAL THRESHOLD output of the 451 is used to trigger the pulse generator. The generator's output pulse is used as an enable input to the 451. As the pulse delay is varied, the measurement window can be "walked" through the pulse. A plot of frequency-versus-delay gives the frequency-versus-time profile of the pulse directly as shown in Figure 3-4. The width of the measurement window is determined by the width of the pulse generator output. Measurement windows of 50 nanoseconds or less can be used, although wider windows yield higher accuracy.

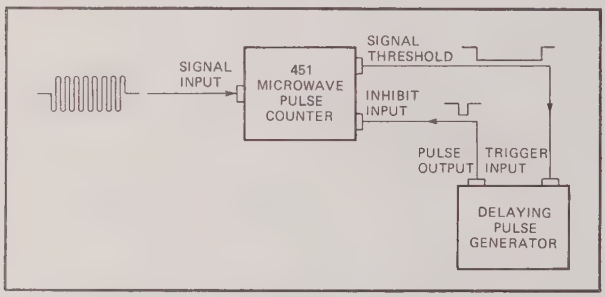


FIGURE 3-3.
PULSE PROFILE MEASUREMENT TEST SET-UP

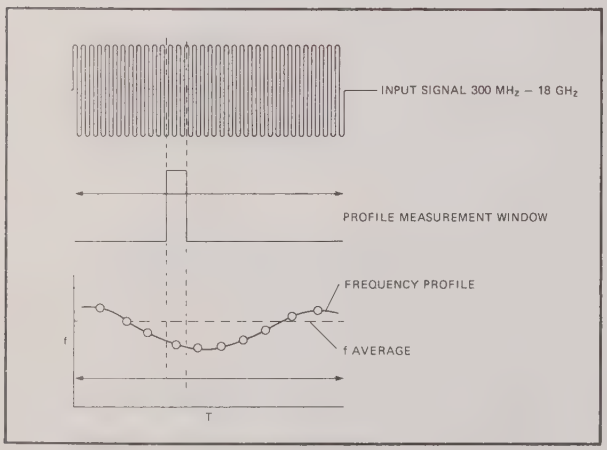


FIGURE 3-4. PULSE PROFILE MEASUREMENT

3-18. DYNAMIC CHARACTERISTICS OF TIME VARYING SIGNALS

3-19. Many complex signals are not pulses at all but simply continuous signals whose frequency varies repetitively with time. One example is the measurement of the response of a device such as a voltage controlled oscillator (VCO). A square wave applied to the tuning voltage will produce a response curve of frequency-versus-time allowing measurement of various settling times such as post-tuning drift. Another possible application would be the measurement of linearity and amplitude for frequency modulated radar altimeter signals. Figure 3-5 shows a test set-up designed to make measurements on time varying signals. It is similar to the pulse profile test set-up, except that in this case since there is always a signal present, a trigger must be obtained from the modulating source. This will trigger the pulse generator which controls the measurement.

3-20. MULTIPLE PULSE SIGNAL MEASUREMENTS

3-21. Another type of measurement is that of a repetitive sequence of pulses differing in frequency. In this case, it is desirable to measure the frequency of each pulse in the sequence separately. The same test set-up as shown in Figure 3-5 is required, with the trigger pulse synchronous with the sequence. In this measurement, the INPUT INHIBIT is used simply to discriminate between pulses. The enabling pulse can be slightly wider than the pulse to be measured. The 451 will automatically restrict the measurement window entirely within the pulse. By shifting the delay time of the enabling pulse, each input pulse of the sequence can be separately measured.

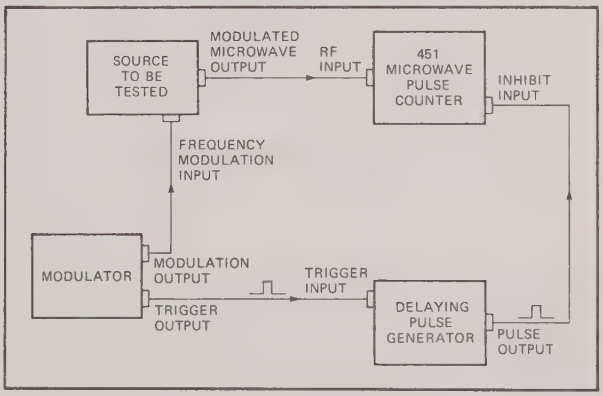


FIGURE 3-5.
TIME VARYING SIGNAL MEASUREMENT TEST SET-UP

3-22. TIMING CONSIDERATIONS

3-23. Under most circumstances, internal timing within the 451 would be of no concern to the user. However, in applications where a few nanoseconds are significant, some details of internal operation are important. These involve two areas: (a) measurement window width, and (b) internal timing delays.

(a) Measurement Window Width

The measurement window is the period during which the GATE is actually open to enable the counting of a signal. This GATE width will typically be 40 nanoseconds narrower than the pulse applied to the INPUT

INHIBIT. The width of the GATE is always an integral number of clock periods (5 nanoseconds). For applications where the measurement window needs to be known to an accuracy better than 20 nanoseconds, it is recommended that the GATE output on the 451 rear panel be observed directly on a high speed oscilloscope. The desired GATE width may then be set by varying the INPUT INHIBIT pulse width. For accurate pulse representation, the oscilloscope input should be terminated in a 50 ohm load.

(b) Internal Timing Delays

When it is necessary to measure the signal frequency at a precise point in time, the internal delays of the measuring instrument can be significant. In the 451, the total delay between the time a signal is applied to an input connector, and the time it is available to be counted, is nominally 70 nanoseconds. The SIGNAL THRESHOLD output on the rear panel of the 451 typically occurs 20 nanoseconds after the signal is applied. The GATE signal at the rear panel occurs at the measurement time with virtually no delay. In other words, when absolute time positioning of a signal is required, it is necessary to consider that the GATE signal, which represents the measurement period, is actually making a measurement of the signal which appeared at the input connector 70 nanoseconds earlier. If the SIGNAL THRESHOLD output is used as an indication of input signal, then it occurs 50 nanoseconds prior to measurement. Figure 3-6 shows the relative timing of these signals for a pulsed input signal. Timing however, is not a function of input signal characteristics.

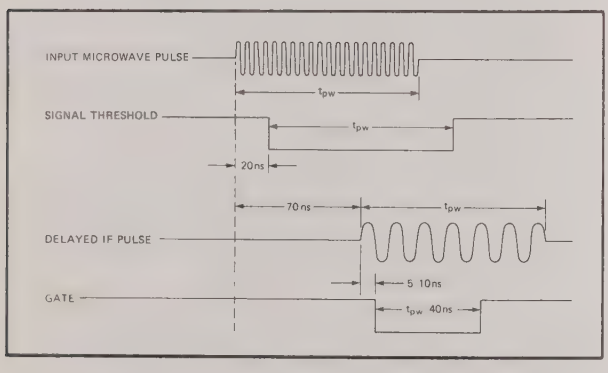


FIGURE 3-6. INTERNAL TIMING DELAYS

3-24. ACCURACY

3-25. In a CW frequency counter, measurement accuracy is generally specified as "time base accuracy ± 1 count". This means that the frequency measurement is in error by the same percentage as the time base reference oscillator. The maximum error in the time base is the sum of various possible errors, such as aging rate, temperature, etc.

3-26. The second type of error: ± 1 count, is derived from the relative timing of gate and signal. Simply stated, if an event occurs every 400 ms (F = 2.5 Hz), a counter could measure either 2 or 3 events in a one second interval.

3-27. There is a third possible source of error in a CW counter: gate error. A gate is supposed to represent a precise number of reference oscillator cycles. Due primarily to differences in the rise and fall times of various circuits, the actual gate will usually be a fixed amount wider or narrower than desired. If this error is less than one period of the maximum input frequency, no counter error will occur. Thus a 300 MHz counter needs a gate accurate to about 3 nanoseconds.

3-28. Each of these three sources of error can contribute to the overall error in pulse frequency measurements. In fact for narrow pulses, the second and third sources of error which are usually ignored in a CW counter, become the dominate sources of error in a pulse counter.

3-29. Time Base Errors

3-30. A frequency error in the time base reference oscillator, results in a proportional frequency measurement error. Two main sources of time base error are: aging rate, and temperature. Aging rates of $< |3 \times 10^{-7}|$/month, and temperature stability of $< |3 \times 10^{-5}|$ over the range of 0 to +50° C, are standard on the 451. An optional temperature compensated crystal oscillator (TCXO) reduces temperature instability to $< |2 \times 10^{-6}|$. By calibration against a frequency standard, this error can be made less than one one count, and thus becomes insignificant.

3-31. Averaging Error

3-32. In order to obtain high resolution, the frequency of a number of measurements is averaged. Each individual measurement has a ± 1 count uncertainty as previously noted. If N measurements are made, then an uncertainty of ± N counts is possible, but very unlikely. The resultant averaged measurement will follow the rules of statistics, in that successive measurements will vary randomly to a certain degree. In fact, most of the readings (63%) will fall between $\pm \sqrt{N}$ counts — this is called the RMS averaging error. N is the number of gates required to accumulate 100 microseconds of gate time. The gate is typically 40 nanoseconds narrower than the input pulse, so the RMS averaging error is:

$$\text{Averaging Error (RMS)} = \frac{100 \text{ kHz}^*}{\sqrt{PW - .04}}$$

* 200 kHz for Band A

where PW = pulse width in microseconds.

3-33. Gate Error

3-34. When narrow pulses are counted, the gate is opened many times in order to obtain a high resolution measurement. Each time the gate opens and closes, there will be a small but finite error. The total error is proportional to the number of times the gate is cycled during a measurement, and is thus inversely proportional to the gate width. This error is also related to both temperature and

input frequency. In the 451, the worst case error including all variables, is specified as:

$$\text{Max Gate Error} = \frac{40\ \text{kHz}}{\text{PW} - .04}$$

where PW = pulse width in microseconds.

Unlike averaging error which is random, gate error is systematic, and is not reduced by frequency averaging.

3-35. TECHNIQUES FOR IMPROVING ACCURACY

3-36. In most cases, specified accuracy of the 451 will be more than sufficient to meet measurement requirements. If greater accuracy is required, all three sources of error can be minimized by a combination of error calibration and long term averaging. It is recommended that if very high accuracy is required, the counter include Options P1 (TCXO) and P4 (BCD Output/Remote Programming).

3-37. TIME BASE CALIBRATION

3-38. A frequency error in the time base oscillator results in the same percentage error in the frequency reading for either CW or pulsed signals. By directly measuring the 10 MHz time base frequency at the **10 MHz OUTPUT** connector using a standard of known accuracy, this error can be determined and corrected. As an example, suppose the measured time base output is 10.0001 MHz. The time base is thus 1×10^{-6} high in frequency, and all readings will be 1×10^{-6} low in frequency — a reading at 10 GHz will be 10 kHz low. Instead of correcting the *reading* for this error, a better technique is to set the time base oscillator precisely on frequency. The advantage of a 451 equipped with a TCXO is improved settability and temperature stability.

3-39. LONG TERM AVERAGING

3-40. Averaging error, as noted previously, is simply the result of a random statistical process. As in all such processes, taking a larger number of samples reduces the averaging error. On 451's equipped with BCD Output Option P4, a test set-up as shown in Figure 3-7 allows the random averaging error to be virtually eliminated. The DAC takes the three least-significant-digits and produces an analog voltage which is plotted on a strip chart recorder. The average value of the output can be easily obtained from the strip chart.

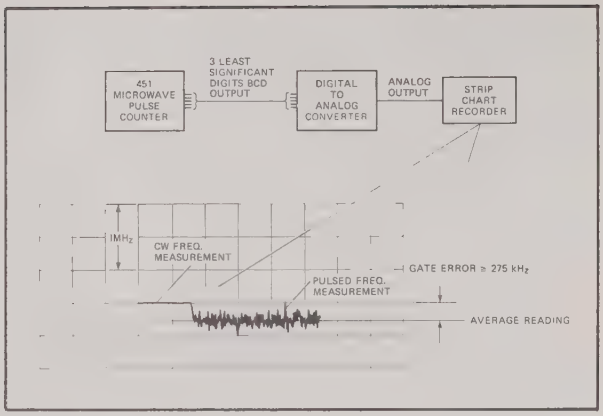


FIGURE 3-7.
CALIBRATION TEST SET-UP (AVERAGING/GATE ERROR)

3-41. GATE ERROR

3-42. Gate error at any given frequency and pulse width can be virtually eliminated — this is accomplished by simulating a pulsed input and determining the gate error. This calibration factor can then be added to, or subtracted from, the indicated measurement to obtain the correct frequency. First, determine the gate error using a CW source at approximately the same frequency (within 25 MHz) as the indicated measurement. A pulsed input is then simulated by applying an ENABLE signal — of the same width as the pulse to be measured — to the **INPUT INHIBIT** connector. Gate error is the difference in reading between the pulsed and non-pulsed measurement of the same CW signal. This procedure provides the true gate error, and avoids error associated with any possible pulling of the signal source. The DAC and strip chart recorder shown in Figure 3-7 can be used to determine the error to a resolution of a few kHz. The result of a typical strip chart is also shown. It should be noted that gate error can be calibrated out of the system for a given pulse width and frequency. However, this calibration procedure will result in additional error for any other pulse width or frequency.

SECTION 4

GENERAL THEORY OF OPERATION

4-1. GENERAL

4-2. The EIP Model 451 Microwave Pulse Counter automatically measures and displays the frequency of a CW or pulsed signal in the range of 925 MHz to 18 GHz (Band B). An optional Prescaler (Option P2) extends this range downward to 300 MHz (Band A). In addition to fully automatic measurements, it is possible to utilize the 451 with accessory equipment to make dynamic frequency measurements — the frequency of any repetitive signal can thus be measured at any point in time. Measurement windows as narrow as 20 nanoseconds are achievable.

4-3. Measurements in Band B (925 MHz - 18 GHz) are achieved by heterodyning the input signal with a known harmonic of 200 MHz. The resulting difference frequency is then processed by a 350 MHz Direct Counter. The counter gate is enabled by the input itself in a manner such that the gate is open only when a signal is present.

4-4. In the Direct Counter, obtainable resolution is inversely proportional to the measurement time. For example: a 1 microsecond gate time will yield 1 MHz resolution. To achieve 10 kHz resolution, the 451 automatically averages as many input pulses as necessary to obtain a total gate interval of 100 microseconds. The required number of pulses is thus a function of the input pulse width. (A more comprehensive discussion of this will be found beginning with paragraph 4-27.)

4-5. In the optional Band A (300 MHz - 950 MHz), the input frequency is divided by four. The divided frequency is then counted in the Direct Counter for a 400 microsecond period to obtain a readout with 10 kHz resolution. As in Band B, gating is controlled by the input signal.

4-6. The system operation of the 451 is best described by separating the instrument into its two main functional blocks: the Microwave Converter, and the Direct Counter.

4-7. Figure 4-1 shows a simplified block diagram of the entire 451. Figure 4-2 shows a more complete block diagram of the Microwave Converter section, while Figure 4-3 diagrams the Direct Counter. Detailed circuit descriptions of all PC boards are given in Section 9.

4-8. MICROWAVE CONVERTER

4-9. The Microwave Converter is a self-contained assembly which performs the function of translating the input microwave frequency downward into the range of 100 to 350 MHz. This translation is accomplished by mixing the incoming signal with a known reference frequency and then amplifying the difference. The input frequency is determined by counting this difference frequency and adding it to the known reference frequency (see Figure 4-2).

4-10. The reference frequency is an integral harmonic of 200 MHz, generated within the YIG Comb Generator (A207). This unit is an integrated assembly containing a harmonic (or comb) generator, and a two-stage YIG filter. The comb generator converts the 200 MHz sine wave input into a train of narrow pulses containing all the harmonics of 200 MHz up to 18 GHz, while the YIG filter selects the desired harmonic. Tuning of the YIG filter is accomplished by varying the current through a pair of coils, which in turn, varies a magnetic field within the structure. (A more comprehensive description of the operation of a YIG-tuned device is given later in this section.)

4-11. The 200 MHz reference is generated within Source/-Amplifier A201 by an LC oscillator which is phase-locked to the 10 MHz Time Base Oscillator (A108) within the 451. This reference is amplified to produce up to one watt of output power to drive the comb generator section of A207. A second output at 200 MHz is used to generate the gate and test functions within the Direct Counter.

4-12. The RF input signal to the Converter section first passes through a Limiter/Attenuator (A206). The limiter portion of this module is a passive diode whose main function is to protect the Mixer (A205) against excessive input power. Protection at levels up to one watt peak or average is provided. The attenuator section contains a multistage, matched PIN diode serving two functions: (a) to provide a means of controlling the RF signal level to the Mixer, and (b) to act as a switch which shuts off the input signal during certain portions of Converter operation.

4-13. The Mixer (A205) is another integrated microwave circuit assembly, containing a hybrid coupler, termination, mixer diode, and a DC return. The Mixer produces two output signals on a common line: (a) an IF signal equal in frequency to the difference between the RF signal and the reference signal; (b) a Video signal resulting from rectification of either the RF or reference input.

4-14. The IF and Video signals are separated in the IF Processor (A204). This assembly contains an IF amplifier, video amplifiers, threshold circuits, and LOCK circuitry. The output of the IF amplifier is the signal actually measured by the Direct Counter. It is also used by the LOCK circuitry to determine the correct reference frequency (comb line). The Converter is considered to be locked when a particular comb line mixes with the applied RF signal to produce an IF signal of proper amplitude and frequency.

4-15. The amplified Video output is used to generate three separate signals: two threshold, and one analog output. One signal — SIGNAL THRESHOLD — is used to detect the presence of sufficient RF signal to initiate operation of the Converter and enable the gate of the Direct Counter. The

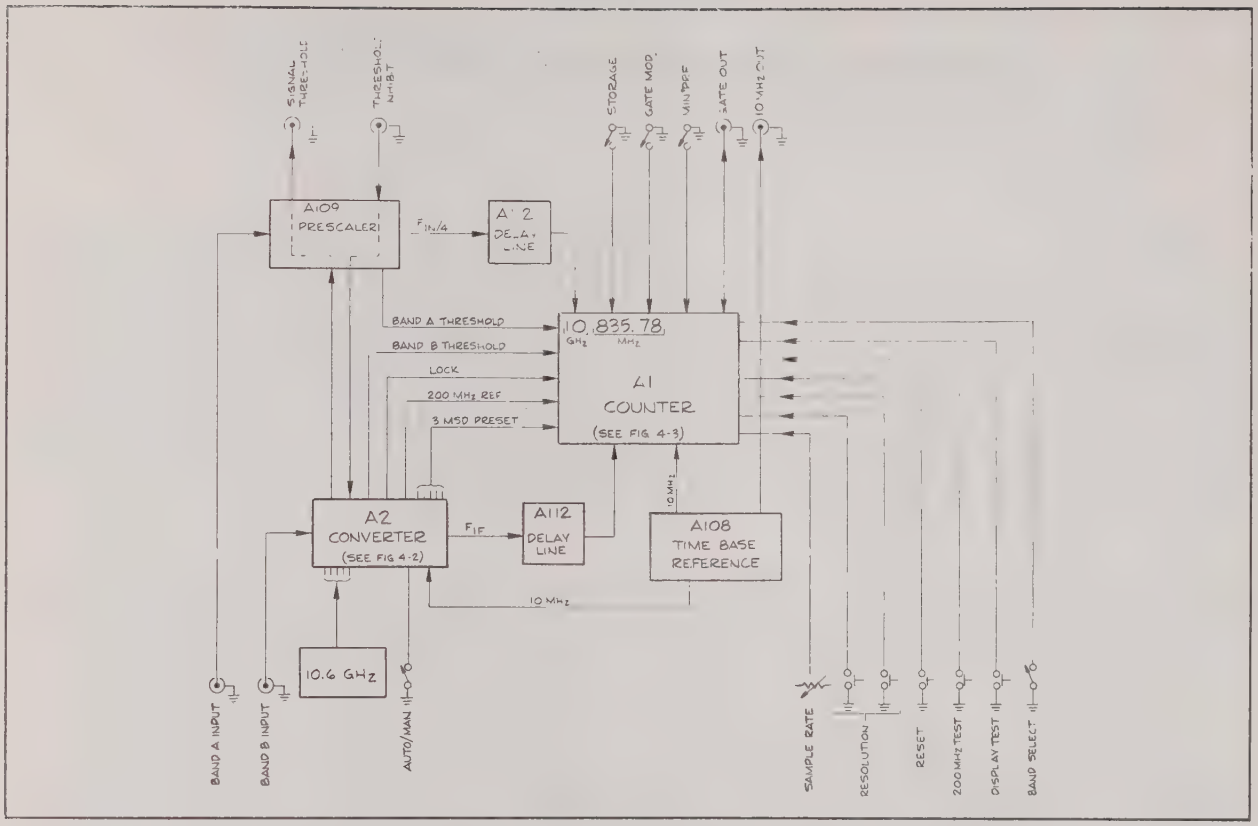


FIGURE 4-1. BLOCK DIAGRAM - 451 MICROWAVE PULSE COUNTER

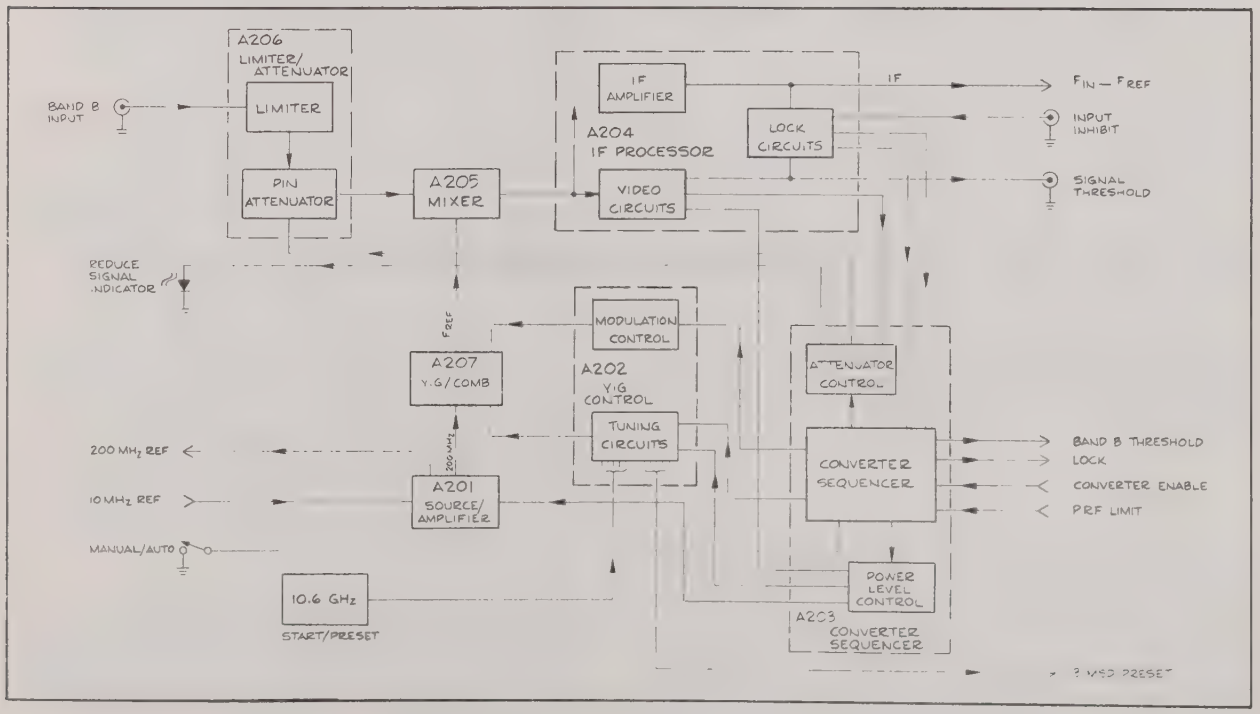


FIGURE 4-2. BLOCK DIAGRAM - 451 PULSE COUNTER - CONVERTER (A2)

second threshold — ATTENUATOR CONTROL — is activated at a level approximately 7 dB above SIGNAL THRESHOLD, and causes the attenuator to reduce the input signal level. The third signal is an analog output corresponding to the amplitude of the reference signal, and is used in the process of stepping from one comb line to another.

4-16. YIG Control board A203 contains all the functions necessary to step the YIG filter to the proper comb line. The primary circuits are a YIG Driver to supply the required current, a digital-to-analog converter (DAC) to set the approximate center frequency, and a centering circuit to precisely center the YIG filter passband on a comb line. The centering process involves modulating the YIG center frequency via an auxiliary modulation coil in the YIG structure. The modulation circuitry is also located on the YIG Control PC board.

4-17. The remaining major assembly in the Converter is the Converter Sequencer (A203). This assembly contains the power level control function to set comb line amplitude, the attenuator control function, and the Converter Sequencer — which acts as the major control unit for the entire Converter. (A detailed operational sequence is given in Section 9).

4-18. 350 MHz DIRECT COUNTER

4-19. After an RF signal is translated into the range below 350 MHz, the frequency is determined by the 350 MHz Direct Counter. This is accomplished by accumulating the number of cycles of the signal which occur within a precisely determined time interval. This interval is based on the frequency of the Time Base Oscillator. In the 451, the total time interval used is 100 microseconds, which yields 10 kHz resolution. In order to measure narrow pulses to this resolution, it is necessary to add together the number of cycles counted in each of a large number of pulses, until the required total time interval is obtained.

4-20. The Direct Counter consists of several major functional blocks as shown in Figure 4-3. Input signals are applied to High Frequency board A106, where they are processed into a standardized signal suitable for counting. This signal then passes through the counter gate to the first decade of the counting chain, which accumulates the input count. The output of this decade goes to the Count Chain (A103) which contains the remaining six decades. A103 also includes the storage unit which holds all the digital information of the previous reading.

4-21. Information display is controlled by Count Chain Control (A102), which contains all the required multiplexing circuitry to drive the Display (A110). The logic to suppress leading zeros on the display is also on A102.

4-22. Overall control of the 451 Counter is performed by the Control board (A104). This assembly generates the counter operating sequence, and interfaces with most of the operating controls as well as the Converter and Prescaler.

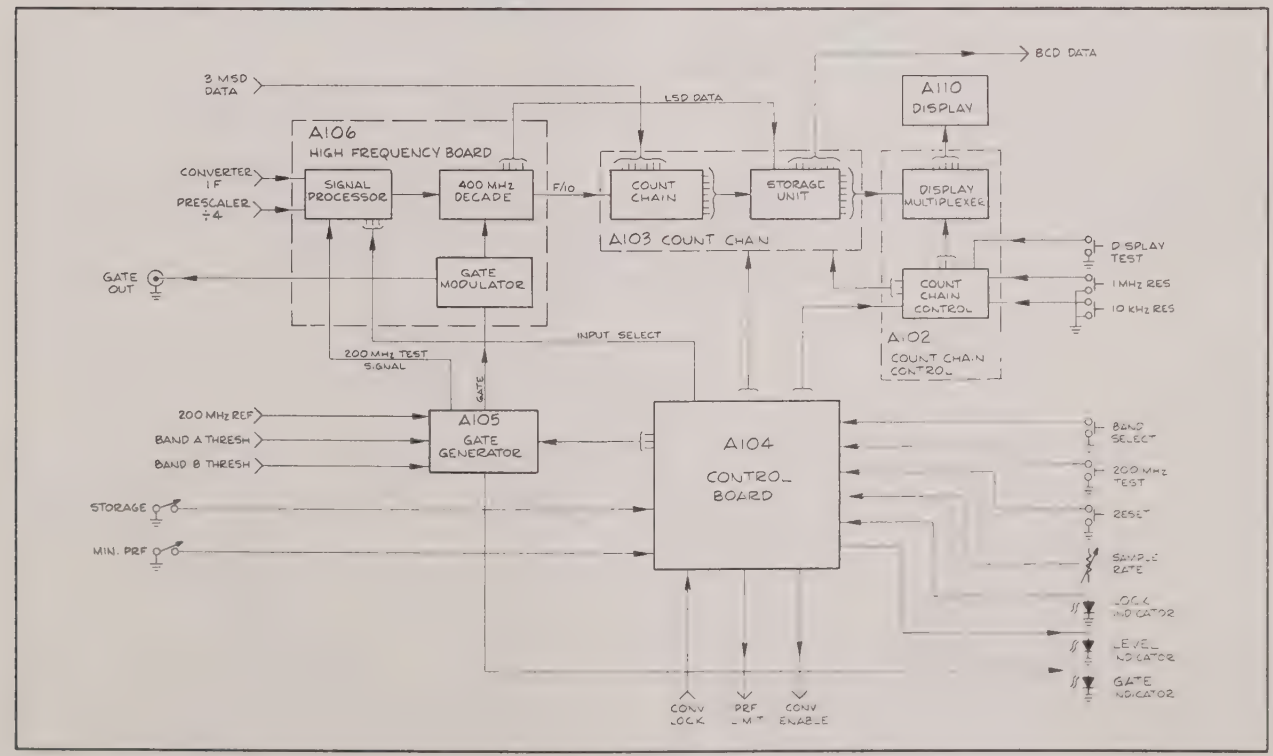


FIGURE 4-3. BLOCK DIAGRAM - 451 PULSE COUNTER - DIRECT COUNTER (A1)

4-23. GATE GENERATOR

4-24. The remaining function of the counter, that of generating a precision gate, is accomplished by the Gate Generator (A105). This function is considerably more difficult for pulsed signals than it is for CW signals, and it is on this function that the overall accuracy of the 451 depends. Two separate operations are performed — the first is to supply a GATE to the High Frequency board which is present only when an input signal is also present. The second is to accumulate the total time during which the GATE is applied, until 100 microseconds is reached.

4-25. The first operation requires that the GATE begin after the signal is present at A106, and end prior to the end of the signal. This is accomplished by generating a GATE approximately 40 nanoseconds shorter than the RF signal (as determined by the SIGNAL THRESHOLD level). The arrival time at A106 of the IF from the Converter (or Prescaler), is then controlled by a delay line so the GATE will fall entirely within the IF pulse.

4-26. The second operation is accomplished by counting clock pulses whenever the GATE is open, until a total time of 100 microseconds is obtained. This requires that each GATE opening is for an exact integral number of clock pulses. A 200 MHz clock is used for this, causing the GATE width to be increased in 5 nanosecond steps until a total of 20,000 clock pulses is accumulated.

4-27. ACCURACY

4-28. In the case of a CW measurement, absolute accuracy is determined almost entirely by the Time Base Reference frequency accuracy. In turn, this accuracy is a function of initial calibration and reference stability with time and temperature.

4-29. The remaining inaccuracy is the digital counting error, specified as ± 1 count, and is normally insignificant in CW measurements. It results from the fact that the number of periodic events that occur in a fixed time interval can vary by one, depending upon the phase of the signal.

4-30. When considering pulse measurement accuracy, the digital counting error can become highly significant, especially for narrow pulses. This results from the fact that the error is a random error, which occurs every time the GATE is opened. Since the error is random, it is subject to statistical fluctuations. This averaging error is proportional to $\sqrt{N}$, where N is the number of times the GATE is opened during a measurement. This, in turn, can be related directly to pulse width:

$$\text{Averaging Error (RMS)} = \frac{100 \text{ kHz}^*}{\sqrt{PW - .04}}$$

* 200 kHz for Band A

where PW = pulse width in microseconds.

Since the averaging error is random, its contribution to overall measurement error can be made arbitrarily small by mathematically averaging multiple readings.

4-31. The second source of error in pulse measurement is GATE error. This error results from a GATE which is not an exact intregral multiple of the clock period. In the measurement of narrow pulses, GATE errors of small fractions of a nanosecond can be significant. Each time the GATE is opened, a fixed error is introduced. As a result, the error is proportional to the number of times the GATE is opened. This is a systematic error and will not average out as will the averaging error. The worst case GATE error, including all effects of frequency and temperature, is given by:

$$\text{GATE Error (max)} = \frac{40 \text{ kHz}}{PW - .04}$$

where PW = pulse width in microseconds.

If necessary, GATE error at any particular frequency and pulse width, can be calibrated out of the counter.

AN INTRODUCTION TO YIG FILTERS

Highly polished spheres of single crystal YIG (yttrium-iron-garnet), have a property called ferrimagnetic resonance. Basically, the ferrimagnetic resonance phenomenon can be explained in terms of spinning electrons creating a net magnetic moment in each molecule of a YIG crystal (see Figure A). Viewing the material macroscopically, there is no net effect because the magnetic dipoles associated with each molecule are randomly oriented (see Figure B). The application of an external magnetic biasing field, H_{DC}, causes the magnetic dipoles to be aligned in the direction of the biasing field (see Figure C).

An RF field can be used to create an orthogonal magnetic force. If the frequency of the RF field coincides with the natural precession frequency, there is a strong interaction called ferrimagnetic resonance (Figure D).

Figure E shows the basic elements of a YIG bandpass filter. The filter consists of a YIG sphere at the center of two loops. The two loops are perpendicular to each other and to the dc biasing field, H_{DC}. One loop carries the RF input and the other the RF output. When the RF signal frequency is the same as the natural precession frequency of the YIG, there is strong coupling between the input and output loops. Thus RF can only pass through the YIG filter at resonance. The resonant frequency is a linear function of the magnetic biasing field, H_{DC}. Generally, H_{DC} is provided by locating the YIG spheres between the poles of an electromagnet, and tuned by varying the current to the magnetic coils.

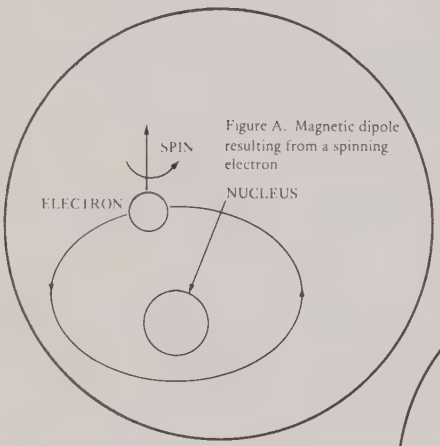


Figure A. Magnetic dipole resulting from a spinning electron

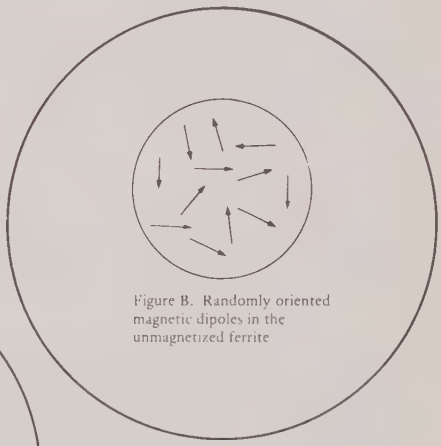


Figure B. Randomly oriented magnetic dipoles in the unmagnetized ferrite

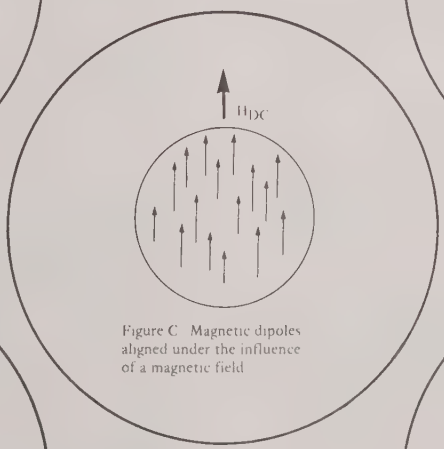


Figure C. Magnetic dipoles aligned under the influence of a magnetic field

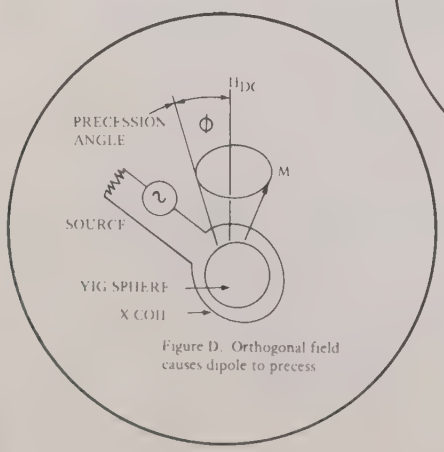


Figure D. Orthogonal field causes dipole to precess

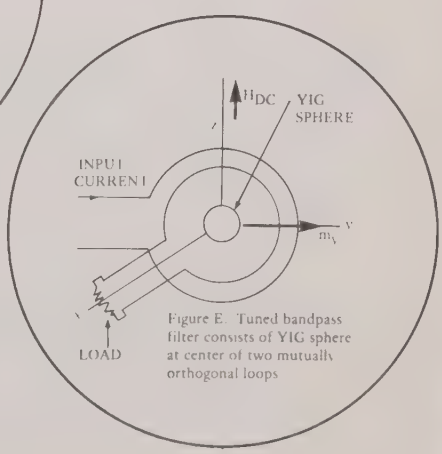


Figure E. Tuned bandpass filter consists of YIG sphere at center of two mutually orthogonal loops

SECTION 5

MAINTENANCE & SERVICE

5-1. GENERAL

5-2. This section provides instructions, procedures, and information necessary to maintain, troubleshoot, and repair the EIP 451 Microwave Pulse Counter.

5-3. FUSE REPLACEMENT

5-4. The counter uses one fuse, located in the POWER INPUT module on the rear panel. For proper operation, use only the fuse specified — do not increase fuse rating or change fuse type. Power module PC board should display the correct nominal line voltage when installed in the module. TO CHANGE TO ANOTHER LINE VOLTAGE:

a. Slide open power module cover and rotate FUSE PULL to the left.

b. Select operating voltage by orienting PC board so nominal supply line voltage appears on the top left side of the PC board. Push board firmly into module slot. (NOTE: When board is completely inserted, only the selected operating voltage will be visible.)

c. Rotate FUSE PULL back into normal position and insert fuse in holder, taking care to select correct fuse value. Close module cover.

d. For 100/120 VAC operation, use a 1.5 A, Slow-Blow, 3AB/MDX type fuse. For 220/240 VAC operation, use a 0.75 A, Slow-Blow, 3AB/MDL type fuse.

5-5. AIR CIRCULATION

5-6. During operation of the counter, the internal fan draws in cooling air through the vents in the rear panel. If these vents are blocked, the temperature inside the enclosure may rise to the point where counter stability is reduced, and component life shortened.

5-7. COUNTER SERVICING

5-8. Recommended Service Procedures:

a. To remove plug-in PC boards: Turn off power to counter. Ease PC board out of its socket by lifting up on board handles. Remove carefully to avoid placing strain on any connecting cables.

b. To unplug flat ribbon cables: Turn off power to counter. Remove PC board as necessary. Use an IC Extractor Tool (EIP P/N: 5000094 or equivalent) to unplug flat ribbon connector.

c. To remove PCB socket locating key: Key must be turned 90° before removal from or re-insertion into socket to avoid contact damage. Use long-nose pliers for removal or insertion.

d. Internal cable and harness routing is shown both in Figure 9-1 and inside the top cover of the counter.

e. Circuit descriptions of PC board and modular assemblies are shown on the same pages (in Section 9) as the related schematic diagram and component layout.

f. Troubleshooting Trees shown later in this section are intended only as a guide, and do not describe every possible failure situation. To speed troubleshooting of a board, replace the board with a known good one.

g. A listing of recommended test equipment for servicing, calibration, and performance testing, is given in Table 5-1. Other equipment may be used provided performance equals or exceeds that listed.

5-9. Servicing Precautions

a. The following assemblies should be replaced instead of being serviced in the field due to the specialized test equipment and procedures required for recalibration: Source/Amplifier (A201), IF Processor (A204).

b. If the following assemblies are repaired either at EIP or in the field, recalibration in the associated counter will be required for proper operation: Gate Generator (A105), High Frequency (A106), YIG Control (A202), Converter Sequencer (A203).

> CAUTION
>
> DO NOT ATTEMPT REPAIR OR DISASSEMBLY OF THE FOLLOWING COMPONENTS: MIXER (A205), PIN LIMITER/ATTENUATOR (A206), YIG COMB GENERATOR (A207), OR TCXO TIME BASE OSCILLATOR (ON A108).

5-10. FACTORY SERVICE

5-11. If the counter is to be returned to EIP for service or repair, BE SURE TO INCLUDE THE FOLLOWING INFORMATION WITH THE SHIPMENT:

a. Name and address of owner.

b. Model and complete serial number of counter.

c. A COMPLETE description of trouble (e.g: under what conditions did trouble occur? What was the signal level? What associated equipment was attached or connected to the counter? Did that equipment fail too?)

d. Name and telephone number of someone familiar with the problem who may be contacted by EIP for any further information if necessary.

e. Shipping address to which counter is to be returned; include any special shipping instructions.

f. Pack the counter for shipment as follows:

(1) Wrap the counter in plastic or heavy kraft paper, and repack in the original shipping container (if still available) using the original packing material.

(2) If the original container and packing material are no longer available, use a heavy (275 lb. test) double-walled carton, with approximately 4" of suitable packing material between the inner and outer walls, with additional packing material as required between the counter and the inner carton. Seal with strong filamentary tape or strapping.

(3) Mark shipping container to indicate that it contains fragile electronic instruments. Ship to EIP at address shown on title page of this manual.

5-12. TROUBLESHOOTING

5-13. MALFUNCTION AT TURN ON

5-14. If the counter fails to turn on (no display, no fan, etc.), make the following checks:

a. Power module PC board correctly inserted and fuse good (see paragraph 5-4).

b. Power cord plugged into counter and into active AC power source.

c. POWER switch at "on" position (button depressed and green indicator showing).

d. PC boards and connectors are properly engaged.

e. Power supply voltages correct (measure at A100J3); refer to paragraph 6-8 for acceptable tolerances.

5-15. FAILURE TO INDICATE ALL ZEROS

5-16. If counter turns on, but fails to indicate all zeros with no applied signal, CHECK THAT:

a. No RESOLUTION switches are depressed.

b. Rear panel MIN PRF switch is in 50 Hz position.

c. PC boards and connectors are properly engaged.

d. Power supply voltages correct.

e. Perform Visual Display Test by pressing DISPLAY TEST switch on front panel. Display should show the numeral "8" in all decade positions.

f. If counter fails the Visual Display Test refer to Troubleshooting Tree Figure 5-4. If counter displays all eights but a digit is missing, refer to Figure 5-5. If the display does not show all zeros when it should, refer to Figure 5-6.

5-17. MALFUNCTION IN SELF TEST

5-18. If counter turns on, but fails to indicate a reading of 200.00 (200 MHz) in the TEST mode, CHECK THAT:

a. Counter indicates all zeros with no applied signal.

b. PC boards and connectors are properly engaged.

c. Power supply voltages correct.

d. Counter passes Visual Display Test (para. 5-16).

e. Refer to Figure 5-7.

5-19. MALFUNCTION IN BAND A (OPTION P2) (300 MHz to 950 MHz)

5-20. If counter fails to read frequency correctly, CHECK THAT:

a. BAND SELECT switch is in the Band A position.

b. A signal of the proper level and frequency range is applied to the Band A input connector.

c. If signal input is correct, counter should indicate all zeros when signal is removed. If not, refer to paragraph 5-16.

d. Counter passes Visual Display Test (para. 5-16).

e. Counter operates correctly in TEST mode. If not, refer to paragraph 5-18.

f. Refer to Figure 5-8.

5-21. MALFUNCTION IN BAND B (925 MHz to 18 GHz)

5-22. If counter fails to read frequency correctly, CHECK THAT:

a. BAND SELECT switch is in the Band B position.

b. A signal of the proper level and frequency range is applied to the Band B input connector.

c. If signal input is correct, counter should indicate all zeros when signal is removed. If not, refer to paragraph 5-16.

d. Counter passes Visual Display Test (para. 5-16).

e. Counter operates correctly in TEST mode. If not, refer to paragraph 5-18.

f. YIG Control (A202) and Converter Sequencer (A203) PC board and co-ax connectors are properly engaged.

g. Refer to Figure 5-9.

5-23. CONVERTER MALFUNCTION

5-24. Source/Amplifier (A201) Power Output Check:

a. Turn off counter power. Remove cable from A201J2.

b. Connect a co-ax cable to A201J2 which is connected to a 30 dB, 1 watt attenuator. Output of the attenuator should be fed to a broadband calibrated detector. CAUTION: 1 watt at 200 MHz can appear at A201J2.

c. Turn on counter. Set counter to Band B.

d. Apply a +5 dBm, 1 - 18 GHz signal to the Band B input connector.

e. Check that Source/Amplifier (A201) has correct power supply voltages, 10 MHz Reference, and Power Reference inputs.

f. Connect dual-trace scope Channel A to A201FL1 (2 V/div), and Channel B to detector output.

g. Set Channel B sensitivity for full scale deflection at 0 dBm into detector (1 W at A201J2).

h. Channels A and B should have similar waveforms, with maximum detector output approximating 1 watt at A201J2 (see Figure 5-1).

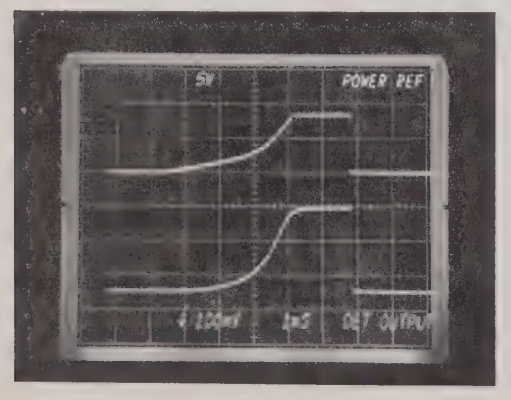


FIGURE 5-1
SOURCE/AMPLIFIER
POWER REF/DETECTED OUTPUT

5-25. Source/Amplifier Spurious Signal Check:

a. Connect A201J2 through a 30 dB, 1 watt attenuator to a spectrum analyzer.

b. Remove wire connected to A201FL1. Connect FL1 to a variable 0 to +8 VDC source. Vary the DC level to FL1 and observe the spectrum from 100 MHz to 400 MHz for spurious signals.

5-26. Front End Check:

a. Turn off counter power. Remove Converter tray (A2), and cover from IF Processor module (A204).

b. With Converter tray out of counter, reconnect tray to counter power at A200P1. Turn on power to counter.

c. Apply a signal in the 1 - 18 GHz range at +5 dBm to the Band B input connector.

d. Remove cable at A204J4 (Attenuator Control), then depress RESET button.

e. Monitor IF input at A204J8; a DC voltage between 50 to 250 mV should be indicated. If output is not in this range, either the Mixer (A205) or the Limiter/-Attenuator (A206) is faulty. CAUTION: Static discharge and/or voltage present at the input of some DVM's can damage the Mixer diode. Connect cables to test equipment, and discharge the center conductor before measuring the output at J8.

f. Re-install and reconnect above assemblies if OK.

5-27. Mixer Check:

a. Turn off counter power. Remove screws holding IF Processor (A204) to Converter tray (A2).

b. Remove co-ax inputs to Mixer (A205).

c. Unplug and remove IF Processor (A204).

d. Remove the two screws holding Mixer to IF Processor, and remove the Mixer.

e. Apply a 0 dBm signal in the 1 - 18 GHz range to the Mixer RF input port (see Figure 5-3). Monitor DC output with oscilloscope at IF converter port (connector that plugs into IF Processor). A DC voltage between 50 and 250 mV should be indicated.

f. Re-install and reconnect above assemblies if OK.

5-28. PIN Limiter/Attenuator Check:

a. Turn off counter power. Remove Converter tray (A2).

b. Remove PIN Limiter/Attenuator (A206) from tray.

c. Disconnect PIN Limiter/Attenuator from Converter Sequencer (A203). Unplug co-ax input to Mixer (A205).

d. Apply +7 VDC to A206P1 pin 4, and -8 VDC to A206P1 pin 1, with common to ground lug on module. CAUTION: Static discharge to these control input pins can damage the Limiter/Attenuator.

e. Apply a 0 dBm signal in the 1 - 18 GHz range to the type N connector. Output should be between -7 and -8 dBm.

f. Re-install and reconnect above assemblies if OK.

5-29. YIG Comb Generator Check:

a. Carefully remove co-ax cable connecting YIG Comb Generator output (A207J1) and Mixer (A205P1).

b. Connect a 1 - 18 GHz broadband calibrated detector to A207J1. The detector output should match Figure 5-2.

c. Check that the YIG Comb Generator (A207) has the proper inputs:

(1) 0 to 2 volt positive-going ramp at YIG Control A202J3 pin 5.

(2) RF power at A207J2 (from Source/Amplifier).

NOTE: Due to the special test equipment required to thoroughly test the performance of the YIG Comb Generator, the above check is adequate only as an indication of a complete failure.

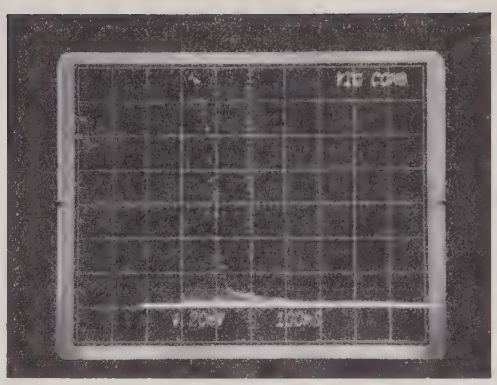


FIGURE 5-2
YIG COMB GENERATOR
DETECTED OUTPUT

EQUIPMENT DESCRIPTION	MFR	MODEL	Section 5 - Service	Section 6 - Calibration	Section 7 - Performance
Signal Source:					
(1) 300 MHz - 1.4 GHz	Wavetek	2001B	x	x	x
(2) 1 GHz - 18 GHz	S-D	521-series	x	x	x
(3) 300 MHz - 18 GHz Pulse Modulator (or Pulse Generator)*	IEC	P23		x	x
Oscilloscope: Dual Trace, 200 MHz Bandwidth	Tektronix	475	x	x	x
Digital Voltmeter ($4\frac{1}{2}$ digit)	Dana	4800	x	x	
Power Meter	HP	432B	x	x	x
Thermistor Mount (10 MHz-18 GHz)	HP	8478	x	x	x
Crystal Detector	HP	8472A		x	
20 dB Directional Coupler	HP	779D		x	
Variable 115 Vac Source	Staco	3PN501			x
Extender Card	EIP	2020021	x	x	
Adapter Cable (SMC to BNC)	EIP	2040015	x	x	
Misc. Attenuators, adapters, and cables			x	x	x

*See paragraph 6-15.

TABLE 5-1
RECOMMENDED TEST EQUIPMENT

5-30. IF Processor Check:

a. Turn off counter power. Disconnect both co-ax inputs to Mixer (A205).

b. Remove IF Processor (A204) from Converter tray. Keep A204P1 (power plug) connected to A200J1.

c. Connect IF Processor to two signal generators as shown in Figure 5-3. Terminate A204J3 in 50 ohms.

d. Turn on counter.

(Signal Threshold Detector Check)

e. Connect oscilloscope 10X probe to A204J6 ($\overline{\text{Band B Threshold}}$).

f. Set LO signal source for 1 GHz ± 1 MHz at -16 dBm, and apply to LO Mixer port (see Figure 5-3).

g. Set RF signal source to 1.2 GHz. Vary RF level from -30 to -20 dBm. A204J6 should go low before RF level reaches -21 dBm.

(Converter Inhibit Check)

h. Set RF source to -20 dBm. Terminate A204J5 in 50 ohms.

i. Verify that A205J6 is at an ECL high (-0.8 VDC). Remove 50 ohm termination.

(Attenuator Control Check)

j. Connect oscilloscope Chan. A 10X probe to A204J4 (Attenuator Control), and Chan. B 10X probe to A204J1 (Converter Threshold).

k. Vary RF source level from below -20 dBm to above -10 dBm. Observe the following:

(1) When RF level is below -20 dBm, A204J1 (ECL level) and A204J4 (TTL level) are <u>both</u> high.

(2) As the level of the RF source is increased, A204J1 goes low. Note this level.

(3) A204J4 goes low 6 to 8 dB higher than A204J1 went low.

(In-Band Detector/Lock Logic Check)

l. Connect Channel A 10X probe to A204J7 (Lock).

m. Set RF source to -20 dBm with 1 kHz square wave modulation. Tune RF source from 1.4 GHz <u>down</u> to 1.0 GHz. Check that the Lock signal goes high (ECL level) at 1.327 GHz ± 3 MHz. Note this frequency.

n. Tune RF source from 1.0 GHz to 1.4 GHz. Check that the Lock signal goes high at 1.100 GHz ± 5 MHz, and then goes low at a frequency 25 to 30 MHz higher than that measured in step m above.

(Detected Modulation Check)

o. Set RF source to 1.2 GHz at -30 dBm. Modulate RF source with 1.5 microsecond pulses at a 20 kHz repetition rate.

p. Connect Channel A 10X probe to A204J2 (Detected Modulation). Output should be 1.5 microsecond positive pulses at 1.6 to 2.4 V amplitude (referenced to -6 volts from A204Q13).

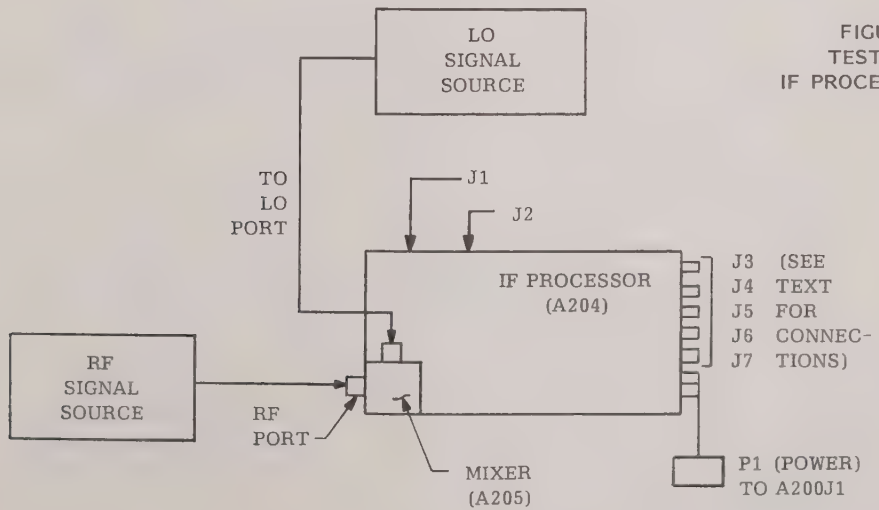


FIGURE 5-3
TEST SET-UP
IF PROCESSOR (A204)

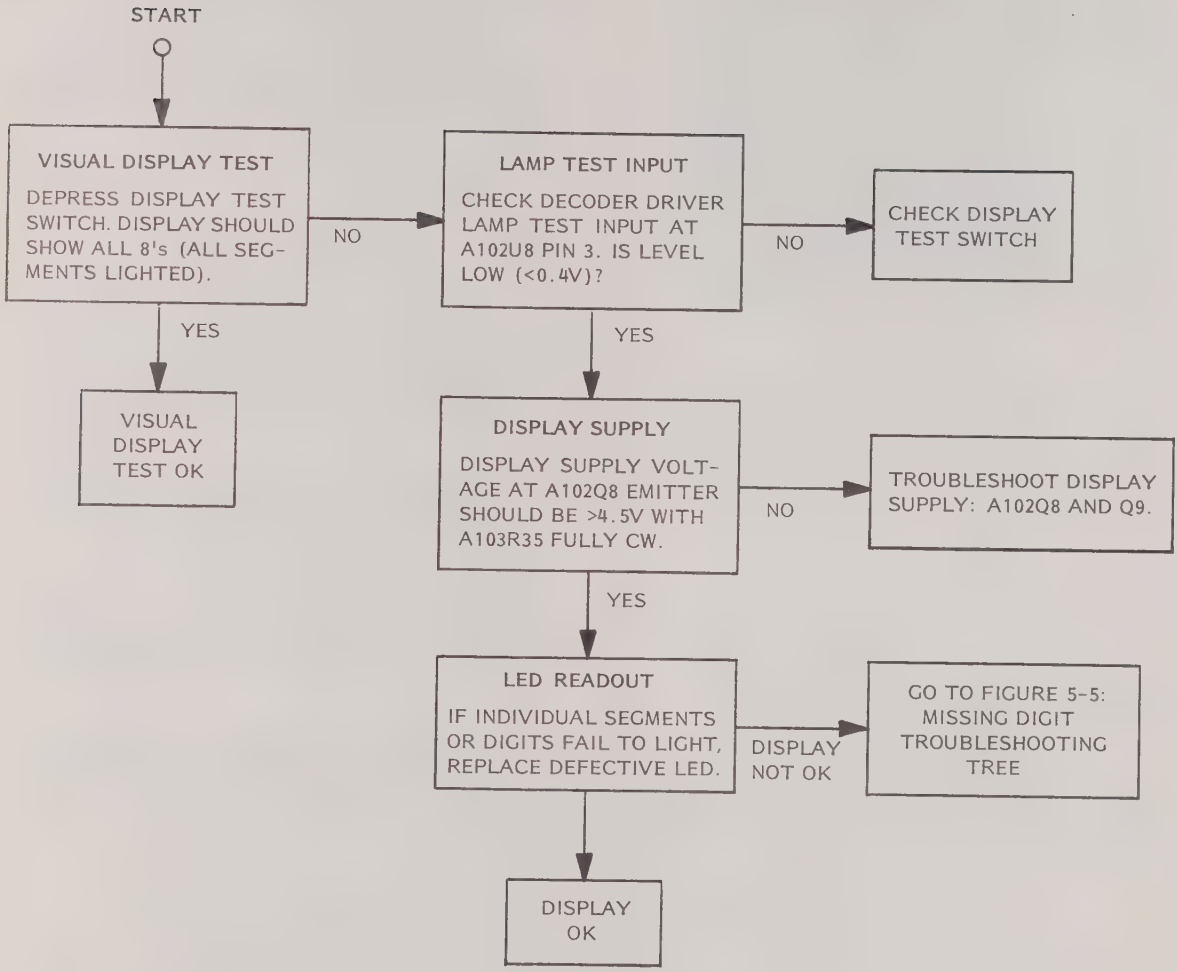


FIGURE 5-4
VISUAL DISPLAY TEST
TROUBLESHOOTING TREE

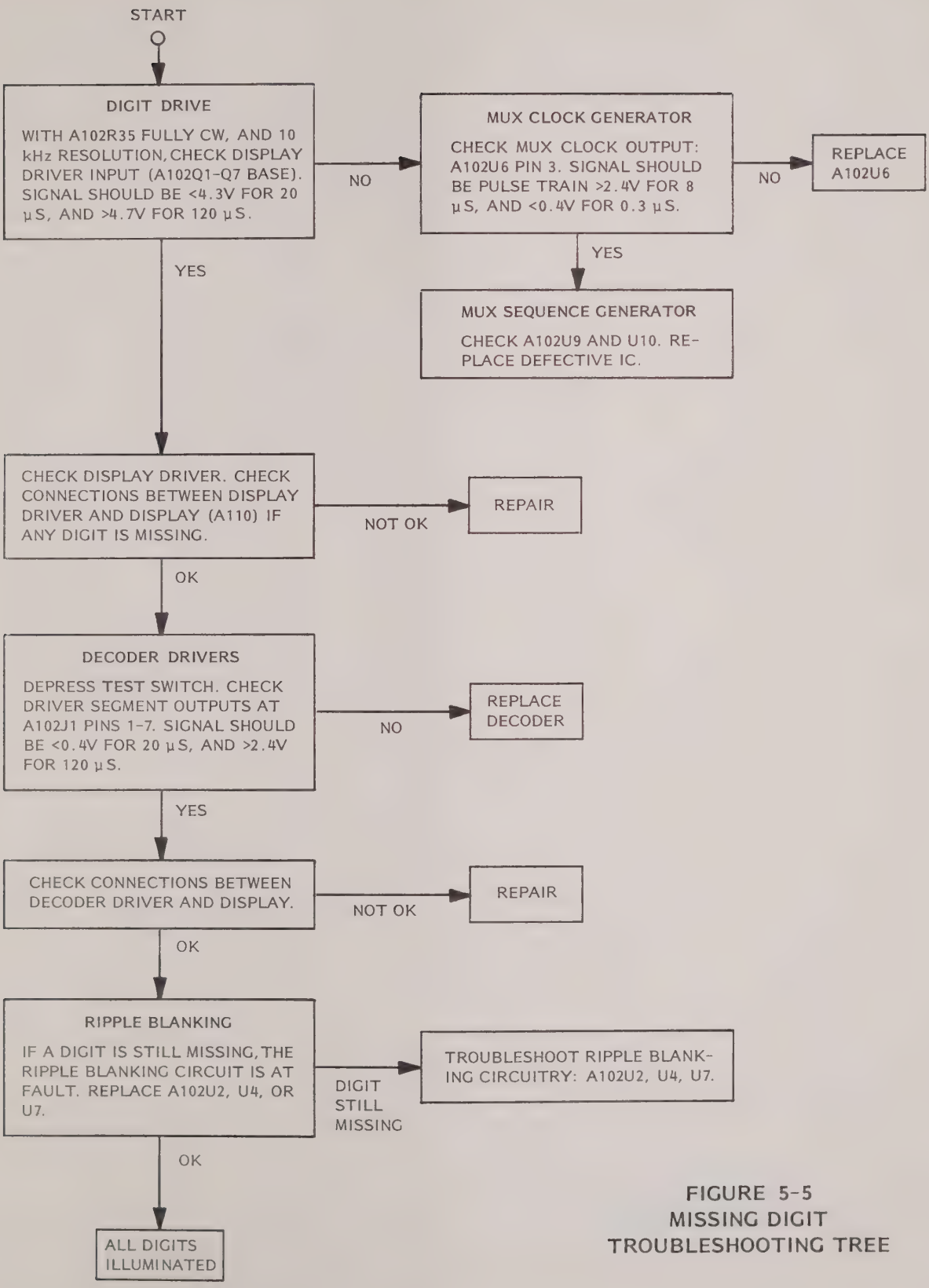

START
DIGIT DRIVE
WITH A102R35 FULLY CW, AND 10 kHz RESOLUTION, CHECK DISPLAY DRIVER INPUT (A102Q1-Q7 BASE). SIGNAL SHOULD BE <4.3V FOR 20 µS, AND >4.7V FOR 120 µS.
NO
MUX CLOCK GENERATOR
CHECK MUX CLOCK OUTPUT: A102U6 PIN 3. SIGNAL SHOULD BE PULSE TRAIN >2.4V FOR 8 µS, AND <0.4V FOR 0.3 µS.
NO
REPLACE A102U6
YES
MUX SEQUENCE GENERATOR
CHECK A102U9 AND U10. REPLACE DEFECTIVE IC.
YES
CHECK DISPLAY DRIVER. CHECK CONNECTIONS BETWEEN DISPLAY DRIVER AND DISPLAY (A110) IF ANY DIGIT IS MISSING.
NOT OK
REPAIR
OK
DECODER DRIVERS
DEPRESS TEST SWITCH. CHECK DRIVER SEGMENT OUTPUTS AT A102J1 PINS 1-7. SIGNAL SHOULD BE <0.4V FOR 20 µS, AND >2.4V FOR 120 µS.
NO
REPLACE DECODER
YES
CHECK CONNECTIONS BETWEEN DECODER DRIVER AND DISPLAY.
NOT OK
REPAIR
OK
RIPPLE BLANKING
IF A DIGIT IS STILL MISSING, THE RIPPLE BLANKING CIRCUIT IS AT FAULT. REPLACE A102U2, U4, OR U7.
DIGIT STILL MISSING
TROUBLESHOOT RIPPLE BLANKING CIRCUITRY: A102U2, U4, U7.
OK
ALL DIGITS ILLUMINATED

FIGURE 5-5
MISSING DIGIT
TROUBLESHOOTING TREE

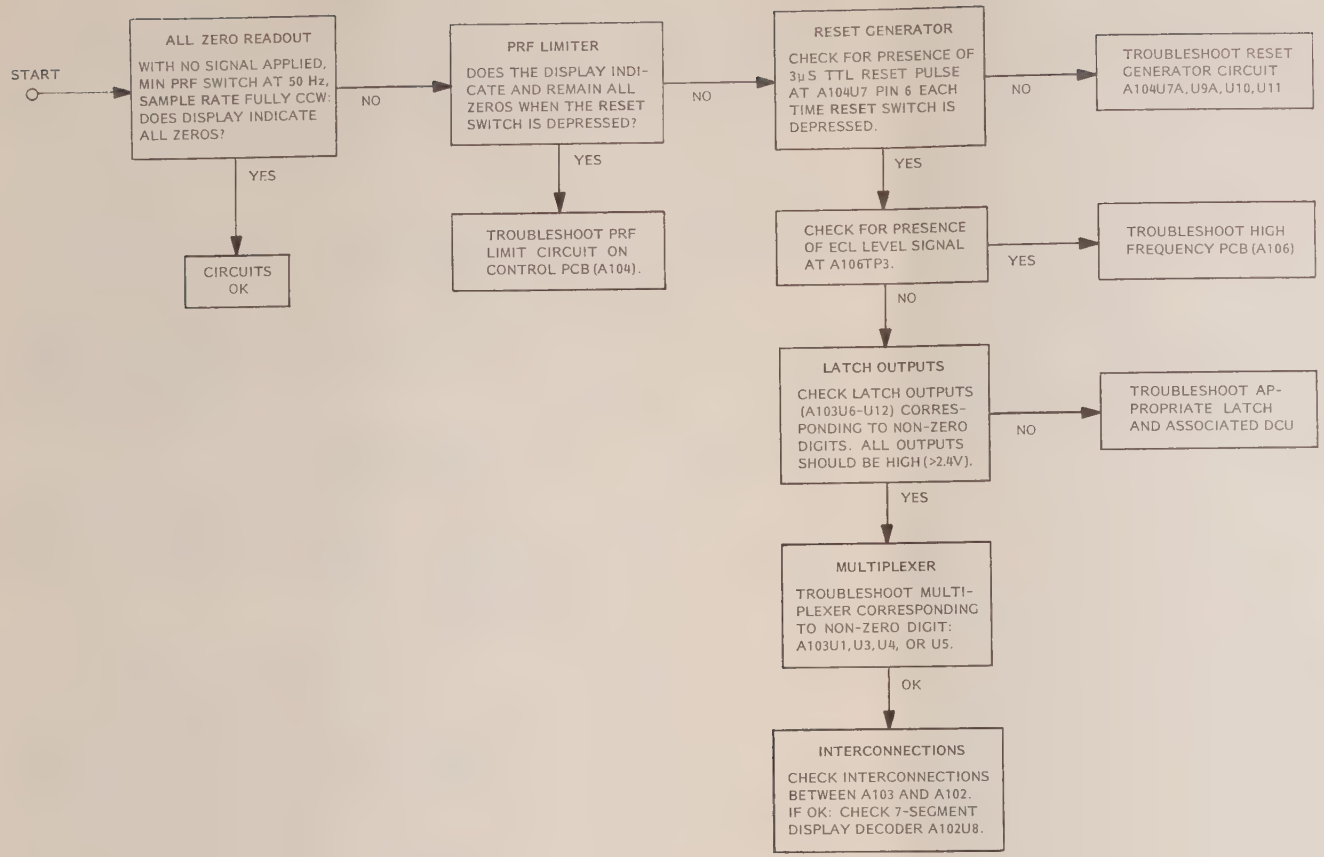
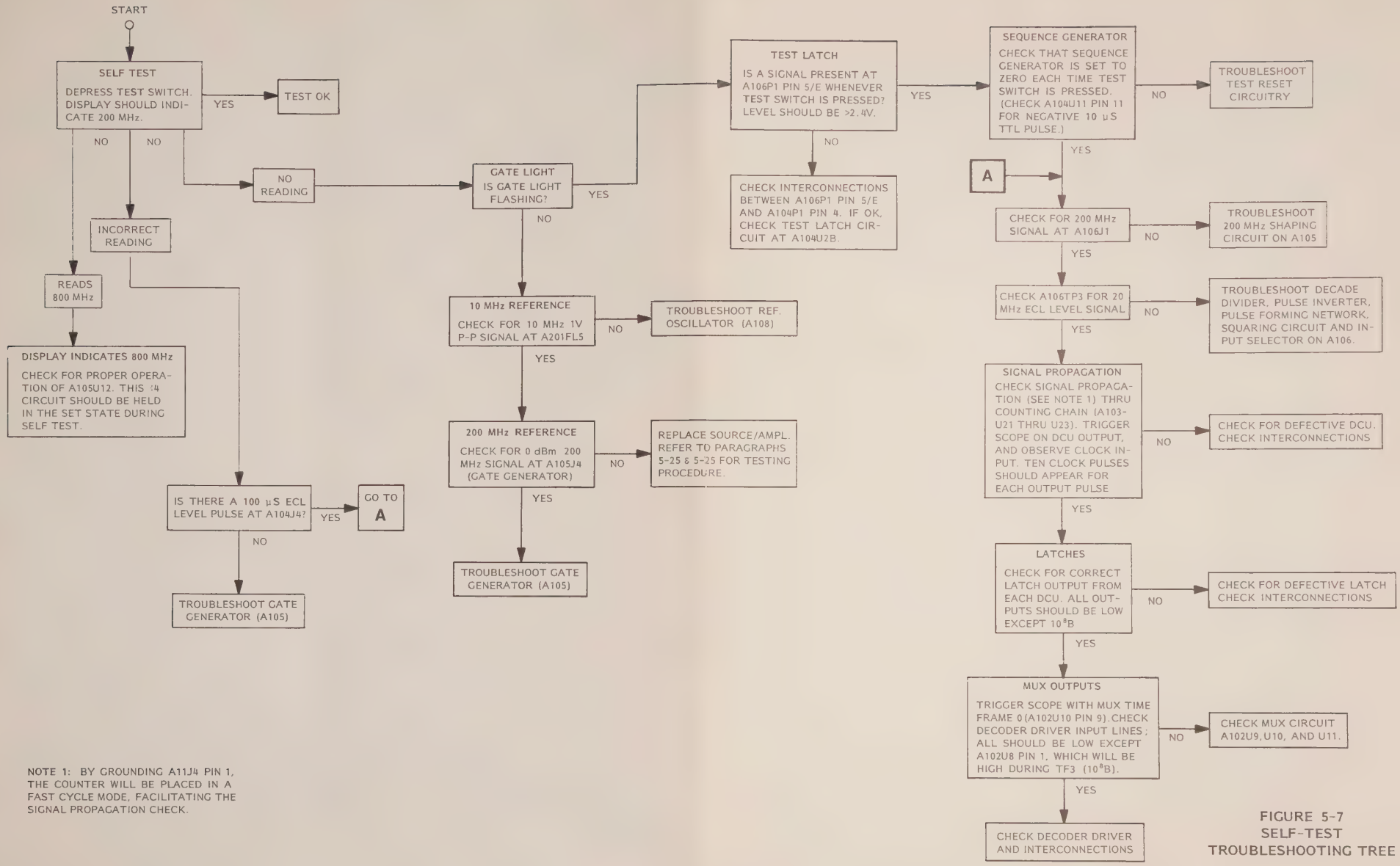

START
ALL ZERO READOUT
WITH NO SIGNAL APPLIED, MIN PRF SWITCH AT 50 Hz, SAMPLE RATE FULLY CCW: DOES DISPLAY INDICATE ALL ZEROS?
NO
YES
CIRCUITS OK
PRF LIMITER
DOES THE DISPLAY INDICATE AND REMAIN ALL ZEROS WHEN THE RESET SWITCH IS DEPRESSED?
NO
YES
TROUBLESHOOT PRF LIMIT CIRCUIT ON CONTROL PCB (A104).
RESET GENERATOR
CHECK FOR PRESENCE OF 3μS TTL RESET PULSE AT A104U7 PIN 6 EACH TIME RESET SWITCH IS DEPRESSED.
NO
TROUBLESHOOT RESET GENERATOR CIRCUIT A104U7A, U9A, U10, U11
YES
CHECK FOR PRESENCE OF ECL LEVEL SIGNAL AT A106TP3.
YES
TROUBLESHOOT HIGH FREQUENCY PCB (A106)
NO
LATCH OUTPUTS
CHECK LATCH OUTPUTS (A103U6-U12) CORRESPONDING TO NON-ZERO DIGITS. ALL OUTPUTS SHOULD BE HIGH (>2.4V).
NO
TROUBLESHOOT APPROPRIATE LATCH AND ASSOCIATED DCU
YES
MULTIPLEXER
TROUBLESHOOT MULTIPLEXER CORRESPONDING TO NON-ZERO DIGIT: A103U1, U3, U4, OR U5.
OK
INTERCONNECTIONS
CHECK INTERCONNECTIONS BETWEEN A103 AND A102. IF OK: CHECK 7-SEGMENT DISPLAY DECODER A102U8.

FIGURE 5-6
NON-ZERO DISPLAY
TROUBLESHOOTING TREE


START
SELF TEST
DEPRESS TEST SWITCH. DISPLAY SHOULD INDICATE 200 MHz.
YES
TEST OK
NO
NO
NO READING
INCORRECT READING
READS 800 MHz
DISPLAY INDICATES 800 MHz
CHECK FOR PROPER OPERATION OF A105U12. THIS ÷4 CIRCUIT SHOULD BE HELD IN THE SET STATE DURING SELF TEST.
IS THERE A 100 µS ECL LEVEL PULSE AT A104J4?
YES
GO TO A
NO
TROUBLESHOOT GATE GENERATOR (A105)
GATE LIGHT
IS GATE LIGHT FLASHING?
YES
NO
10 MHz REFERENCE
CHECK FOR 10 MHz 1V P-P SIGNAL AT A201FL5
NO
TROUBLESHOOT REF. OSCILLATOR (A108)
YES
200 MHz REFERENCE
CHECK FOR 0 dBm 200 MHz SIGNAL AT A105J4 (GATE GENERATOR)
NO
REPLACE SOURCE/AMPL. REFER TO PARAGRAPHS 5-25 & 5-25 FOR TESTING PROCEDURE.
YES
TROUBLESHOOT GATE GENERATOR (A105)
TEST LATCH
IS A SIGNAL PRESENT AT A106P1 PIN 5/E WHENEVER TEST SWITCH IS PRESSED? LEVEL SHOULD BE >2.4V.
YES
NO
CHECK INTERCONNECTIONS BETWEEN A106P1 PIN 5/E AND A104P1 PIN 4. IF OK, CHECK TEST LATCH CIRCUIT AT A104U28.
SEQUENCE GENERATOR
CHECK THAT SEQUENCE GENERATOR IS SET TO ZERO EACH TIME TEST SWITCH IS PRESSED. (CHECK A104U11 PIN 11 FOR NEGATIVE 10 µS TTL PULSE.)
NO
TROUBLESHOOT TEST RESET CIRCUITRY
YES
A
CHECK FOR 200 MHz SIGNAL AT A106J1
NO
TROUBLESHOOT 200 MHz SHAPING CIRCUIT ON A105
YES
CHECK A106TP3 FOR 20 MHz ECL LEVEL SIGNAL
NO
TROUBLESHOOT DECADE DIVIDER, PULSE INVERTER, PULSE FORMING NETWORK, SQUARING CIRCUIT AND INPUT SELECTOR ON A106.
YES
SIGNAL PROPAGATION
CHECK SIGNAL PROPAGATION (SEE NOTE 1) THRU COUNTING CHAIN (A103-U21 THRU U23). TRIGGER SCOPE ON DCU OUTPUT, AND OBSERVE CLOCK INPUT. TEN CLOCK PULSES SHOULD APPEAR FOR EACH OUTPUT PULSE
NO
CHECK FOR DEFECTIVE DCU. CHECK INTERCONNECTIONS
YES
LATCHES
CHECK FOR CORRECT LATCH OUTPUT FROM EACH DCU. ALL OUTPUTS SHOULD BE LOW EXCEPT 10^8B
NO
CHECK FOR DEFECTIVE LATCH CHECK INTERCONNECTIONS
YES
MUX OUTPUTS
TRIGGER SCOPE WITH MUX TIME FRAME 0 (A102U10 PIN 9). CHECK DECODER DRIVER INPUT LINES; ALL SHOULD BE LOW EXCEPT A102U8 PIN 1, WHICH WILL BE HIGH DURING TF3 (10^8B).
NO
CHECK MUX CIRCUIT A102U9, U10, AND U11.
YES
CHECK DECODER DRIVER AND INTERCONNECTIONS

NOTE 1: BY GROUNDING A11J4 PIN 1, THE COUNTER WILL BE PLACED IN A FAST CYCLE MODE, FACILITATING THE SIGNAL PROPAGATION CHECK.

FIGURE 5-7
SELF-TEST
TROUBLESHOOTING TREE

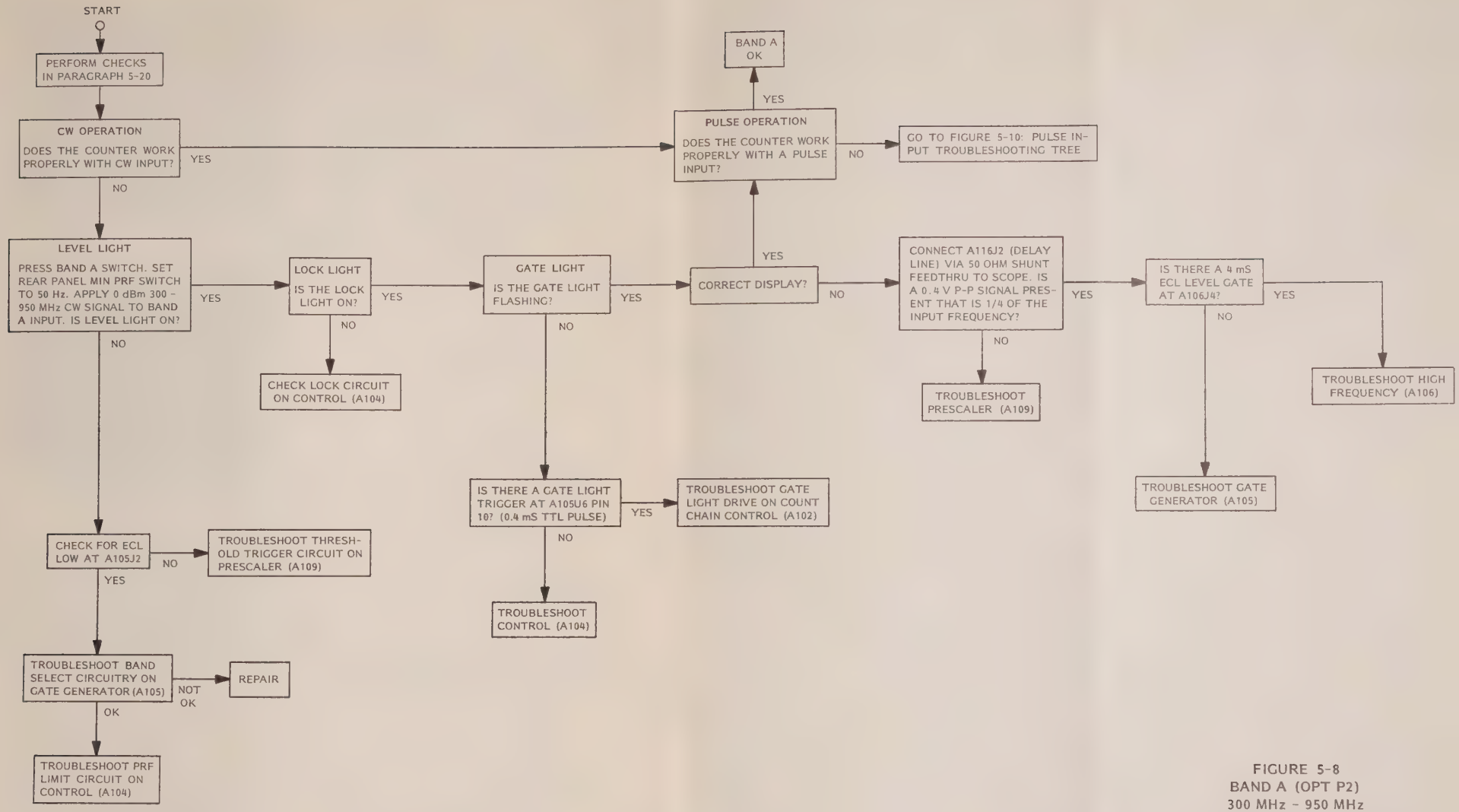

START
PERFORM CHECKS IN PARAGRAPH 5-20
CW OPERATION
DOES THE COUNTER WORK PROPERLY WITH CW INPUT?
YES
NO
PULSE OPERATION
DOES THE COUNTER WORK PROPERLY WITH A PULSE INPUT?
NO
GO TO FIGURE 5-10: PULSE INPUT TROUBLESHOOTING TREE
YES
BAND A OK
LEVEL LIGHT
PRESS BAND A SWITCH. SET REAR PANEL MIN PRF SWITCH TO 50 Hz. APPLY 0 dBm 300 - 950 MHz CW SIGNAL TO BAND A INPUT. IS LEVEL LIGHT ON?
YES
NO
LOCK LIGHT
IS THE LOCK LIGHT ON?
YES
NO
CHECK LOCK CIRCUIT ON CONTROL (A104)
GATE LIGHT
IS THE GATE LIGHT FLASHING?
YES
NO
CORRECT DISPLAY?
YES
NO
CONNECT A116J2 (DELAY LINE) VIA 50 OHM SHUNT FEEDTHRU TO SCOPE. IS A 0.4 V P-P SIGNAL PRESENT THAT IS 1/4 OF THE INPUT FREQUENCY?
YES
NO
TROUBLESHOOT PRESCALER (A109)
IS THERE A 4 mS ECL LEVEL GATE AT A106J4?
YES
NO
TROUBLESHOOT HIGH FREQUENCY (A106)
TROUBLESHOOT GATE GENERATOR (A105)
IS THERE A GATE LIGHT TRIGGER AT A105U6 PIN 10? (0.4 mS TTL PULSE)
YES
NO
TROUBLESHOOT GATE LIGHT DRIVE ON COUNT CHAIN CONTROL (A102)
TROUBLESHOOT CONTROL (A104)
CHECK FOR ECL LOW AT A105J2
NO
YES
TROUBLESHOOT THRESHOLD TRIGGER CIRCUIT ON PRESCALER (A109)
TROUBLESHOOT BAND SELECT CIRCUITRY ON GATE GENERATOR (A105)
NOT OK
REPAIR
OK
TROUBLESHOOT PRF LIMIT CIRCUIT ON CONTROL (A104)

FIGURE 5-8
BAND A (OPT P2)
300 MHz - 950 MHz
TROUBLESHOOTING TREE

START

CW OPERATION
PERFORM CHECKS NOTED IN PARAGRAPH 5-22. DOES COUNTER WORK PROPERLY WITH CW INPUT IN BAND B?
YES → GO TO FIGURE 5-10: PULSE INPUT TROUBLESHOOTING TREE
NO

LEVEL LIGHT
SET COUNTER TO BAND B, AUTO SWEEP, 00.0 GHz START FREQ. APPLY 0 dBm, 925 MHz - 18 GHz CW SIGNAL TO BAND B INPUT. IS LEVEL LIGHT ON?
YES

LOCK LIGHT
IS LOCK LIGHT ON?
YES

GATE LIGHT
IS GATE LIGHT FLASHING?
YES

DISPLAY
NO 3 MSD → TROUBLESHOOT COUNT CHAIN (A103)
3 MSD ONLY → IF PROCESSOR
CHECK FOR CORRECT OUTPUT AT A106J3 -2 TO +3 dBm, AT BAND B INPUT FREQ -3MSD
NOT OK → TROUBLESHOOT DELAY LINE, AND IF AMPL/LIMITER ON A204 — SEE NOTE 2
OK → TROUBLESHOOT A106 (HIGH FREQUENCY)
INCORRECT READING → JUMPER A203TP13 TO TP14, AND TP15 TO TP18. DISCONNECT CABLE TO A105J1. PRESS RESET SWITCH. APPLY 0 dBm, 100 - 350 MHz CW SIGNAL TO A112P3. DOES DISPLAY INDICATE THIS FREQ?
NO → TROUBLESHOOT A106 (HIGH FREQUENCY)
YES → TROUBLESHOOT IF PROCESSOR (A204) — SEE NOTE 2

CORRECT READING → GO TO FIGURE 5-10: PULSE INPUT TROUBLESHOOTING TREE

NO → TROUBLESHOOT A105 (GATE GEN)

IS A203U10 (SEQUENCE GENERATOR) CYCLING? (CYCLING IS INDICATED BY A203TP0 GOING LOW PERIODICALLY)
NO → WHICH STATE IS SEQ. GEN. IN?
TP4, 5, 6 LOW → CHECK LOCK LIGHT CKT ON A104, AND LOCK (TTL) ON A203
TP7 LOW → TROUBLESHOOT SEQ. GENERATOR CIRCUIT ON A203
YES → ARE CONVERTER SEQUENCE FUNCTIONS OF CORRECT DURATION? (SEE TABLE 9-15A)
NO → TROUBLESHOOT APPROPRIATE FUNCTION
YES → CHECK FOR RAMP AT A201E1 (SOURCE/AMPL)
NOT OK → CHECK A203 POWER LEVEL CONTROL
OK → CHECK SOURCE/AMPL (A201) PER PARAGRAPH 5-24. REPLACE A201 IF BAD — SEE NOTE 2
IF OK →

BAND B THRESHOLD
IS A203TP14 HELD AT AN ECL LOW* FOR 20µS OR LONGER?
NO → FOR UNITS WITH OPT P2 (BAND A): CHECK FOR ECL LOW* AT A204J5
NO → TROUBLESHOOT A109U1C CIRCUIT
YES → CHECK BAND SELECT CIRCUIT ON A105, LEVEL LIGHT CIRCUIT ON A104, AND INTERCONNECTIONS
YES → CONVERTER SEQUENCER
CHECK FOR TTL LOW SIGNAL AT A203TP0 THRU TP7
TP1 LOW → CHECK POWER LEVEL CONTROL CKT ON A203
TP2, 4, 6 LOW → TROUBLESHOOT SEQ. GENERATOR CIRCUIT ON A203

TP0 LOW → CHECK TTL INPUTS TO RESET GENERATOR: A203U13 PINS 1, 2, 4, AND 5
ALL INPUTS HIGH → CHECK RESET GEN (U3), 40 kHz CLOCK (U18), AND SEQ. GEN ON A203
LOW INPUT → CHECK ASSOCIATED CIRCUIT

TP3 LOW → REMOVE CABLE TO A204J2. DOES A203-TP3 REMAIN LOW?
YES → IS A202TP2 BETWEEN -0.4 AND +0.4 VDC?
YES → CHECK WINDOW DETECTOR, ERROR DAC CONTROL, AND ERROR DAC ON A202
NO → CHECK PHASE DETECTOR AND LOW PASS FILTER CIRCUITS ON A202
NO → PERFORM SLOPE AND OFFSET CALIBRATION PER PARAGRAPH 6-20

TP7 LOW → CHECK ECL LEVEL AT A203TP15
ECL HIGH* → CHECK INTERCONNECTIONS FROM A203TP15 TO A204J7. CHECK IN-BAND DETECTOR ON A204 (IF PROCESSOR)
ECL LOW* → CHECK SEQ. GEN. ON A203

TP5 LOW → JUMPER A203TP16 TO TP21. REMOVE AND GROUND CABLE TO A204J4. IS THERE A NOMINAL 0 TO 1 VOLT HUMP AT A203TP17?
NO → CHECK A203U4-U6 (ATTN RAMP GEN)
YES → REMOVE TP16-TP21 JUMPER. UNGROUND CABLE BUT DO NOT RECONNECT TO J4. PRESS RESET SWITCH. IS DC LEVEL AT A203TP17 APPROXIMATELY -0.5 VDC?
NO → CHECK ATTENUATOR CONTROL CKT ON A203
YES → CHECK DCV AT A203J1. IS PIN 4 +7 V AND PIN 1 -8 V? (REPLACE A204J4 CABLE AFTER CHECK)
NO → CHECK ATTENUATOR DRIVER
YES → CHECK MIXER (A205) PER PARAGRAPH 5-27. CHECK LIMITER/ATTENUATOR (A206) PER PARAGRAPH 5-28. REPLACE IF DEFECTIVE - SEE NOTE 2. IF OK: CHECK VIDEO AMPLIFIER AND SIGNAL THRESHOLD CKTS ON A204.

YIG DRIVER
REMOVE A201P2. IS WAVEFORM AT A202J3 PIN 5 (YIG RAMP) AS SHOWN IN FIG. 5-9A? (RECONNECT A201P2)
NO → CHECK YIG DRIVER CIRCUIT ON A202
YES → YIG COMB GENERATOR
CHECK YIG/COMB GENERATOR (A206) PER PARAGRAPH 5-29
NO → REPLACE A207 (SEE NOTE 1)
YES → TROUBLESHOOT 20 kHz AMPLIFIER AND VIDEO AMPLIFIER ON A204

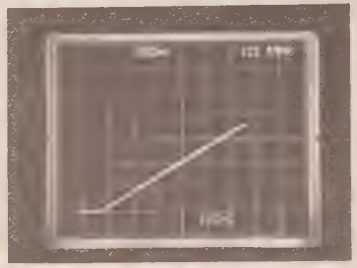


FIGURE 5-9A. YIG RAMP

* ECL HIGH = -0.8 VDC, ECL LOW = -1.7 VDC.

NOTE 1: THE FOLLOWING ASSEMBLIES SHOULD BE REPLACED, NOT REPAIRED, IF DEFECTIVE (SEE PARAGRAPH 5-9): A205 (MIXER), A206 (LIMITER/ATTENUATOR), A207 (COMB GEN).

NOTE 2: THE FOLLOWING ASSEMBLIES REQUIRE SPECIAL CALIBRATION PROCEDURES AND SHOULD BE REPLACED, NOT REPAIRED, IF DEFECTIVE (SEE PARAGRAPH 5-9): A201 (SOURCE AMPLIFIER), AND A204 (IF PROCESSOR)

FIGURE 5-9
BAND B (CONVERTER)
925 MHz - 18 GHz
TROUBLESHOOTING TREE

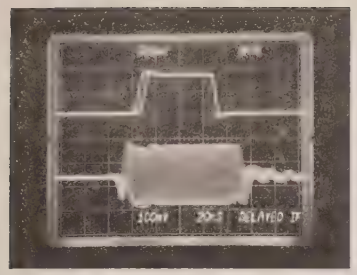


FIGURE 5-10A
DELAYED IF AND GATE SIGNALS

START

DOES COUNTER OPERATE PROPERLY WITH CW INPUT IN BAND A (IF PRESENT), AND BAND B?

NO → REFER TO APPROPRIATE TROUBLESHOOTING TREE

YES

DOES COUNTER OPERATE PROPERLY WITH PULSE INPUT IN BANDS A & B? (SEE NOTE 1).

YES → COUNTER OK

NO

WHICH BAND IS INOPERATIVE FOR PULSE INPUTS?

BOTH BANDS A AND B → CHECK BAND SELECT CIRCUIT ON A105 (GATE GENERATOR)

OK → TROUBLESHOOT HIGH FREQUENCY (A106)

BAND A → SET COUNTER TO BAND A. APPLY 300 MHz, 100 nS, -10 dBm PULSE MODULATED SIGNAL TO BAND A INPUT. CONNECT HIGH FREQUENCY 10X PROBES TO A106J4 (GATE) & A106J2 (DELAYED IF PULSE). SEE NOTE 2.

SET COUNTER TO BAND A. APPLY 300 MHz, 100 nS, -10 dBm PULSE MODULATED SIGNAL TO BAND A INPUT. CONNECT HIGH FREQUENCY 10X PROBES TO A106J4 (GATE) & A106J2 (DELAYED IF PULSE). SEE NOTE 2.

- SIGNAL THRESHOLD GOOD DELAYED IF PULSE BAD → DISCONNECT DELAY LINE FROM A109J2. CONNECT A109J2 THRU 50 OHM SHUNT TO SCOPE. ARE THERE 100 nS, 75 MHz, 0.4V P-P RF PULSES PRESENT?
  - YES → TROUBLESHOOT DELAY LINE (SEE NOTE 3)
  - NO → TROUBLESHOOT ÷4 OR POWER CONTROL CIRCUIT ON PRESCALER
- BOTH SIGNALS BAD OR SIGNAL THRESHOLD BAD → TROUBLESHOOT APPROPRIATE CIRCUIT ON PRESCALER (A109)
- BOTH SIGNALS GOOD → RECONNECT DELAY LINE TO A106J2. IS THERE AN ECL LEVEL PULSE TRAIN AT A106J4?
  - YES → TROUBLESHOOT HIGH FREQUENCY (A106)
  - NO → TROUBLESHOOT GATE GENERATOR (A105)

BAND B → SET COUNTER TO BAND B, MANUAL SELECT, 0.10 GHz PRESET. APPLY 1.12 Hz, 100 nS, -10 dBm PULSE MODULATED SIGNAL TO BAND B INPUT. CONNECT HIGH FREQUENCY 10X PROBES TO A106J4 (GATE) AND A106J3 (DELAYED IF PULSE). SEE NOTE 2.

- GATE SIGNAL BAD DELAYED IF GOOD → ARE THERE 100 nS ECL LEVEL PULSES AT A105J1?
  - YES → CHECK BAND SELECT CIRCUIT ON A105 (GATE GENERATOR)
  - NO → REPLACE OR REPAIR IF PROCESSOR (A204)
- BOTH SIGNALS BAD → REPLACE OR REPAIR IF PROCESSOR (A204)
- BOTH SIGNALS GOOD → TROUBLESHOOT HIGH FREQUENCY (A106)
- GATE SIGNAL GOOD DELAYED IF BAD → DISCONNECT DELAY LINE FROM A204J3. CONNECT A204J3 THRU 50 OHM SHUNT TO SCOPE. ARE THERE 100 nS, 120 Hz, 0.4V P-P PULSES PRESENT?
  - YES → TROUBLESHOOT DELAY LINE (SEE NOTE 3)
  - NO → REPLACE OR REPAIR IF PROCESSOR (A204)

NOTE 1: IF THE PRF OF THE INPUT SIGNAL IS LESS THAN 50 PPS, THE MIN PRF SWITCH SHOULD BE IN THE 0 Hz POSITION

NOTE 2: IN ORDER TO MEASURE THE TRUE TIME RELATIONSHIP BETWEEN THE GATE AND DELAYED IF SIGNALS, IT WILL BE NECESSARY TO TAKE INTO CONSIDERATION THE DIFFERENCE IN TIME DELAY BETWEEN THE TWO CHANNELS OF THE OSCILLOSCOPE. REFER TO FIGURE 5-10A FOR WAVEFORMS, AND FIGURE 3-6 FOR TIMING DELAYS.

NOTE 3: DELAY LINE SPECIFICATIONS: IMPEDANCE: 50 OHMS DELAY: 50 nS. ATTENUATION AT 100MHz: 7 dBm, AT 300 MHz: 13 dBm. COUNTERS EQUIPPED WITH OPTION P2 (PRESCALER) HAVE TWO IDENTICAL DELAY LINES CONTAINED WITHIN ONE ASSEMBLY.

FIGURE 5-10
PULSE INPUT
TROUBLESHOOTING TREE

SECTION 6

ADJUSTMENTS & CALIBRATION

6-1. GENERAL

6-2. This section describes the procedures to be followed to correctly adjust the EIP 451 Microwave Pulse Counter. In general, adjustments should only be made if the instrument is not operating within specifications, or following replacement of components. Recommended test equipment is specified in Table 5-1. If adjustments do not result in specified performance, refer to Section 5.

6-3. GENERATING AND MEASURING NARROW RF PULSES

6-4. There are two potential problem areas that arise when generating narrow RF pulses by modulation of a CW source: (1) frequency pulling due to impedance changes in the modulator, and (2) video leakage of the modulating waveform.

6-5. The input impedance of a modulator generally varies with its state: on, off, or switching. This variation in loading will cause shifts in the frequency of the microwave source. The extent of this pulling effect is dependent upon the type of source, type of modulator, and the degree of isolation between them. Pulling of several megahertz for poorly isolated sources is not uncommon.

6-6. Modulators generally incorporate some form of fast switching diode, whose state is changed by the application of an appropriate bias current or voltage waveform. Coupling capacitors are used to separate the bias lines from the RF circuit. Video leakage is the transient signal caused by the modulating waveform being coupled into the RF lines. Usually this appears as a spike or ringing waveform at the leading and trailing edges of the modulating pulse. If care is not taken to provide adequate filtering, or otherwise eliminate this effect, significant measurement errors can occur, especially for fast rising pulses (approximately 10 nanoseconds). On an unfiltered system, video leakage can exceed applied RF signals by several orders of magnitude.

6-7. In order to measure the peak power of an RF pulse, it will be necessary to use a calibrated crystal detector (such as the HP 8472A), a 50 ohm shunt feedthru to terminate the detector output, and a 50 MHz oscilloscope to observe the detected video pulse. The measurement is made by connecting the detector to the cable that normally feeds the Band A or B input of the counter, with the detector output fed through the shunt to the scope. The observed peak amplitude of the pulse is then compared to the calibration curve of the detector to find the peak pulse power. The 3 dB pulse width is the time interval between the points on the pulse waveform corresponding to one-half the peak power.

IMPORTANT

Many adjustments are dependent upon previous ones. It is essential that care be taken to perform adjustments in exactly the order presented below. Adjustment locations are shown in Figure 6-1.

6-8. POWER SUPPLY ADJUSTMENT

6-9. Prior to any power supply adjustments, the instrument should be allowed to warm-up for at least 20 minutes. All voltages are measured on Counter Interconnect board at A100P3. Adjust basic DC voltages as follows:

a. Connect DVM to ground at A100P3 pin 12.

b. Measure +12 VDC output. Adjust A107R7 until output is +12.000 ± .010 VDC.

c. Measure +5 VDC output. Adjust A107R15 until output is +5.000 ± .010 VDC.

d. Measure -12 VDC output. Adjust A107R21 until output is -12.000 ± .010 VDC.

e. Measure -5.2 VDC output. Adjust A107R31 until output is -5.200 ± .010 VDC.

6-10. TIME BASE CALIBRATION

IMPORTANT

The precision of time base calibration directly affects overall counter accuracy. Reasons for recalibration, and procedures to be used, should be thoroughly understood before attempting any readjustment.

6-11. The fractional frequency error in the frequency indicated by the counter, is equal to the negative of the fractional frequency error of the Time Base Oscillator with respect to its true value. That is:

$$\frac{\Delta f_s}{f_s} = -\frac{\Delta f_t}{f_t}$$

where f_s is the true frequency of the measured signal, and f_t is the true frequency of the Time Base Oscillator. Thus the inaccuracy associated with a frequency meas-

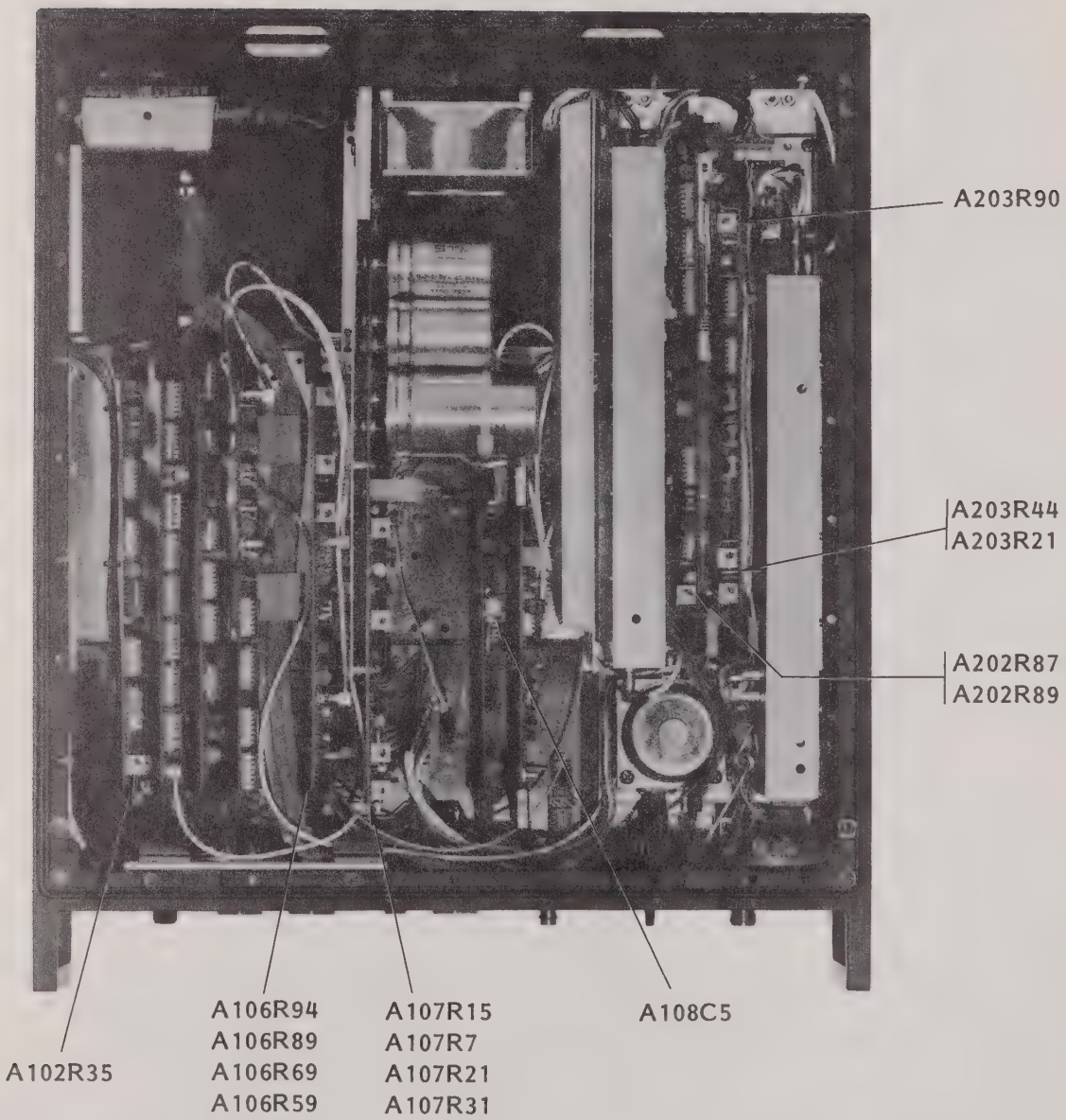


FIGURE 6-1
CALIBRATION
ADJUSTMENT
LOCATOR

urement is directly related to the quality of the Time Base Oscillator, and a measure of the precision with which it was originally adjusted.

6-12. RTO CALIBRATION PROCEDURE

a. Measure the frequency of the RTO (Room Temperature Crystal Oscillator) at the rear panel 10 MHz OUT connector with a second counter of known accuracy.

b. Adjust the RTO (if necessary) by turning A108C5 until the measured frequency is 10 000 000 ± 5 Hz.

6-13. TCXO CALIBRATION (OPTION P1)

6-14. Option P1 consists of a temperature-compensated crystal oscillator (TCXO) mounted in place of the RTO on Oscillator board A108. The highest and lowest actual measured TCXO frequencies will differ by no more than 2 parts in 10^6 if the temperature is varied slowly from 0° to +50°C. Therefore, an indicated measurement will exhibit the same fluctuation even though the signal being measured is not changing. To center this fluctuation on the true value of the measured signal, each TCXO has imprinted on its side, the frequency to which it must be set at +25°C. The calibration procedure for this adjustment is described in paragraph 6-18.

6-15. At approximate room temperature (+25°C), the slope of the frequency vs.temperature curve, is normally no worse than -1×10^{-7} parts per °C. Therefore, if the counter is used in an ordinary laboratory environment, the TCXO may be set as close to 10 000 000 Hz as desired. In this environment, a peak-to-peak temperature variation of 5°C will result in a measured signal error due to oscillator temperature characteristics of no more than $\pm 2.5 \times 10^{-7}$ parts.

6-16. Another source of inaccuracy in the measured signal due to the Time Base Oscillator originates in the natural aging characteristic of the crystal. Aging refers to the long term, irreversible change in frequency, generally in the positive direction, which all quartz oscillators experience. The magnitude of this frequency fluctuation in the TCXO is specified to be less than 3×10^{-7} parts per month. This may be expected to improve in time to be no worse than 1×10^{-6} parts per year in continuous service.

6-17. Error due to aging adds directly to error due to temperature perturbations. Thus the frequency of recalibration is dependent upon the overall accuracy requirement of the counter and its environment. For example: If the counter is subjected to the full operating temperature range and initially adjusted properly, then one month later the inaccuracy over temperature could be expected to vary from $+ 1.3 \times 10^{-6}$ parts, to $- 0.7 \times 10^{-6}$ parts.

6-18. TCXO CALIBRATION PROCEDURE

a. Remove top cover of counter. Connect counter to reliable power source. Note ambient temperature.

b. Measure the frequency of the TCXO at the rear panel 10 MHz OUT connector with a second counter of known calibration accuracy.

c. Adjust the TCXO (if necessary) by turning the calibration screw on the TCXO case until the measured frequency is the same as that shown on the TCXO calibration label.

6-19. BAND A (OPTION P2) ADJUSTMENTS (300 MHz to 950 MHz)

a. If the High Frequency board (A106) is repaired or replaced, perform the adjustments given in paragraph 6-22. No other Band A adjustment is required.

6-20. BAND B ADJUSTMENTS (925 MHz to 18 GHz)

a. 40 kHz Clock Adjustment

NOTE: Required only upon replacement of YIG Comb Generator (A207), or Converter Sequencer board (A203).

(1) Set A203R90 fully ccw (counter-clockwise).

(2) Set counter to Band B, MANUAL SELECT, and 01.0 GHz START FREQUENCY.

(3) Jumper A202TP1 to TP3. Ground A202TP5.

(4) Connect oscilloscope Channel A to A202U1 pin 9, and Channel B to A202U1 pin 4.

(5) Adjust A202R89 for a symmetrical waveform as shown in the upper trace of Figure 6-2. (All pulses in the train should be of equal duration.)

(6) If necessary, select a new value for R93 so the leading and trailing edges of the 20 kHz reference (lower trace) occur in the center of the detected modulation pulses. (If R93 is changed, readjust A202R89 as stated in (5) above.)

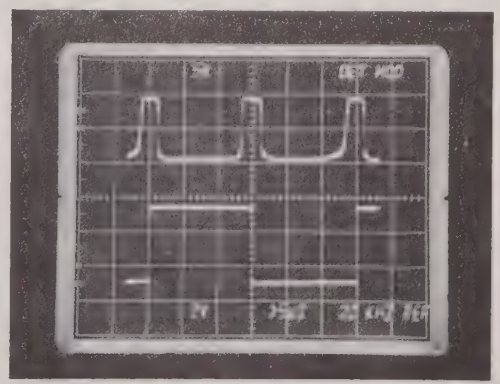


FIGURE 6-2
DETECTED MOD/20 kHz
REFERENCE PULSE TIMING

b. Slope and Offset Adjustments

(1) Repeat paragraph 6-20a(1) through (5).

(2) Change preset in 1 GHz steps from 1 to 18 GHz, adjusting A202R87 to produce a symmetrical waveform across the band.

(3) Readjust A202R89 and R87 as necessary.

(4) Remove jumper from A202TP1 and TP3. Remove ground from A202TP5.

c. Attenuator Driver Adjustments

NOTE 1: These adjustments are difficult to make, and require careful set-up by personnel familiar with microwave return loss measurements. These adjustments affect only the Band B input VSWR of the counter, and should be made only: (1) when it is known that there is excessive input VSWR, (2) the attenuator driver on A203 has been repaired, or (3) if A203 or A206 have been replaced.

NOTE 2: To make a meaningful return loss measurement, use a directional coupler with a minimum directivity of at least 25 dB (Example: HP 779D).

(1) Set counter to Band B, AUTO SWEEP, 00.0 GHz START FREQUENCY.

(2) Carefully set-up equipment as shown in Figure 6-3. Note especially where cables or adapters must not be used (which would degrade accuracy of the adjustment).

(3) Set Limiter/Attenuator (A206) to maximum insertion loss, by connecting a jumper between A203-TP16 and TP21.

(4) Adjust A203R44 for maximum return loss (waveform will be a DC level).

NOTE 3: As R44 is rotated from full ccw to full cw, the amplitude observed on the scope will go from a maximum point through a minimum point and then to a maximum again. Maximum return loss (minimum reflected signal) occurs at the minimum point.

(5) Remove jumper from A203TP16 to TP21.

(6) Cycle Limiter/Attenuator (A206) through its normal operating range by removing and grounding the cable to A204J4.

(7) Inhibit the counter from locking up by jumpering A203TP14 to TP16.

(8) Connect an 0.47uf capacitor across A203C2.

(9) Trigger scope from A203TP17 (Attenuator Control Ramp).

(10) Adjust A203R21 for maximum return loss. See Note 3, and Figure 6-4 for typical waveform.

(11) Remove jumper between A203TP14 and TP16. Remove capacitor. Reconnect cable to A204J4.

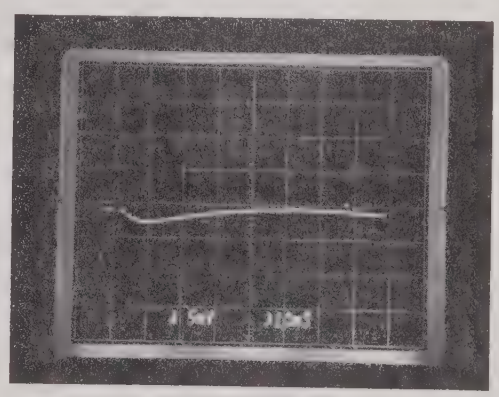


FIGURE 6-4
RETURN LOSS MEASUREMENT

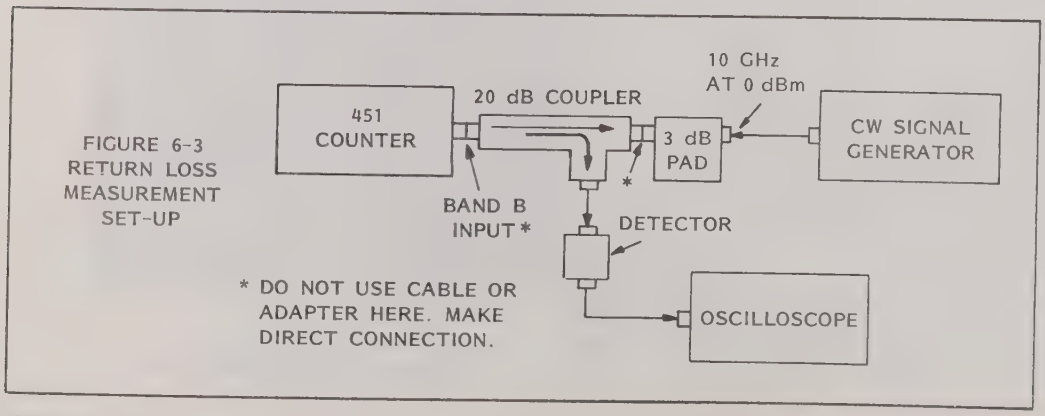


FIGURE 6-3
RETURN LOSS
MEASUREMENT
SET-UP

d. Attenuator Control Adjustments

NOTE: To be performed only upon installation of a new Limiter/Attenuator (A206), or replacement of the Converter Sequencer board (A203).

(1) Connect an 0.47uf capacitor across A203C2.

(2) Connect the Channel A 10X probe of scope to A203J1 pin 1 (I_{series}). Connect Channel B 10X probe to A203TP17.

(3) Remove and ground cable to A204J4.

(4) Connect jumper between A203TP14 and TP16.

(5) Select a value for A203R18 so the first two or three steps of the Attenuator Control Ramp have no effect upon I_{series} (see Figure 6-5).

(6) Remove jumper between A203TP14 and TP16. Remove capacitor. Reconnect cable to A204J4.

(7) Apply a 0 dBm, 1.4 GHz CW signal to Band B input.

(8) Press RESET switch. Increase signal level to the Band B input until the REDUCE SIGNAL light comes on. (Light should come on between +4 and +6 dBm. If it does not, select a new value for A203-R17, and repeat steps (7) and (8) until it does.)

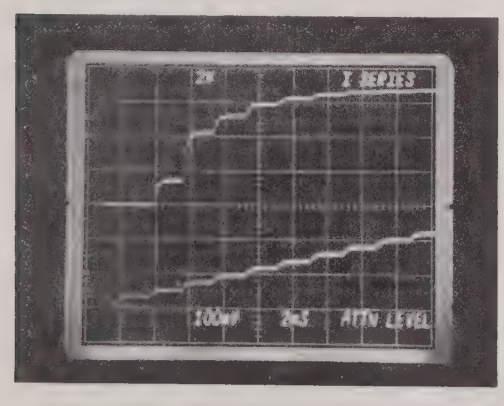


FIGURE 6-5
ATTENUATOR CONTROL
RAMP OFFSET ADJUSTMENT

e. Comb Leveling

(1) Set-up counter as described in paragraph 6-20c(1) and (2).

(2) Jumper A203TP14, TP15, and TP16 together.

(3) Connect Channel A 10X scope probe to A203-TP12. Trigger scope from A203TP20 (Reset).

(4) Press RESET switch.

(5) Adjust A203R64 to level comb lines to 1 volt nominal (see Figure 6-6).

(6) Remove jumpers from TP14, TP15, and TP16.

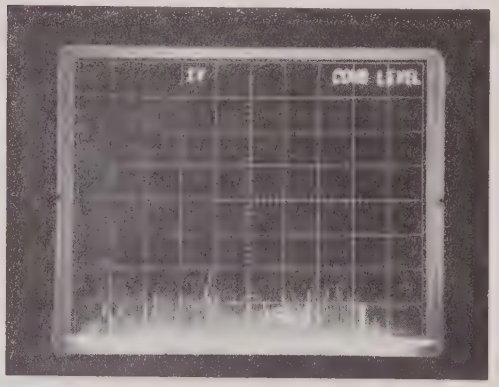


FIGURE 6-6
COMB LEVELING

6-21. DISPLAY BRIGHTNESS ADJUSTMENT

a. Numerical display brightness can be adjusted as desired with A102R35. Turn control clockwise to increase brightness.

6-22. HIGH FREQUENCY (A106) ADJUSTMENTS

a. Noise Modulation

(1) Ground A106TP4.

(2) Adjust A106R94 for zero volts at A106TP13. Remove ground from A106TP4.

(3) Adjust A106R89 for maximum negative voltage at A105TP5, with symmetrical noise at A106TP13 (see Figure 6-7).

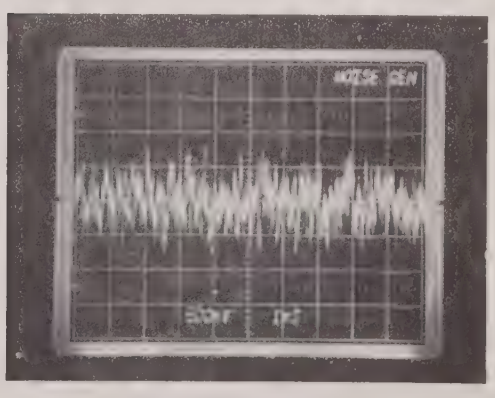


FIGURE 6-7
NOISE GENERATOR

b. Gate Accuracy

(1) Set-up counter as described in paragraphs 7-10 and 7-11.

(2) Adjust A106R59 to minimize difference between averaged pulse reading and CW reading.

NOTE: If using Method 1, it will be necessary to (a) have a stable RF source that will not be pulled more than 10 kHz while being modulated by a 100 ns pulse, (b) have no video information on the RF pulse, and (c) have a means of measuring RF pulse width and amplitude. Also, when using Method 1, adjust A106R59 and R69 so the average pulse reading is centered about the CW reading (gate error equal to zero).

(3) Set rear panel GATE MOD switch to ON. Adjust A106R69 to minimize difference between averaged pulse reading and CW reading.

(4) Repeat steps (2) and (3) as necessary to obtain the same reading during pulse or CW modulation with GATE MOD ON or OFF.

SECTION 7

PERFORMANCE TESTS

7-1. GENERAL

7-2. The purpose of this section is to enable the user to verify that the counter meets specifications over the entire frequency range, with both CW and pulse inputs. NOTE: For the verification of specifications not included in this section, please consult the factory.

7-3. VARIABLE LINE VOLTAGE

7-4. During the performance tests, the counter should be connected to the power source through a variable voltage device, so line voltage can be varied ± 10% from nominal (100/120 or 220/240 VAC), to assure proper operation of the counter under various supply conditions.

7-5. RECOMMENDED TEST EQUIPMENT

7-6. Refer to Table 5-1 for recommended test equipment. Other equipment may be used provided that performance is equal to, or better than, that listed in the table.

7-7. PERFORMANCE TESTS

7-8. RANGE, SENSITIVITY, AND MINIMUM PULSE WIDTH — BAND A (OPTION P2) (300 MHz to 950 MHz)

a. Set SAMPLE RATE control fully counter-clockwise, and BAND SELECT switch to Band A.

b. Connect a CW signal source to the Band A input.

c. Vary source frequency from 300 MHz to 950 MHz at -10 dBm. Counter should display correct frequency.

d. Connect a 100 nanosecond pulse modulated signal source to the Band A input. Set level to -10 dBm. Vary source frequency from 300 MHz to 950 MHz. Counter should display correct frequency. NOTE: Refer to paragraph 6-3 for pulse width measurement.

7-9. RANGE, SENSITIVITY, AND MINIMUM PULSE WIDTH — BAND B (925 MHz to 18 GHz)

a. Set SAMPLE RATE control fully counter-clockwise, BAND SELECT switch to Band B, AUTO SWEEP, and 00.0 GHz START FREQUENCY.

b. Connect a CW leveled source to the Band B input.

c. Vary source frequency from 925 MHz to 18 GHz at the following levels:

925 MHz - 10 GHz:	-10 dBm
10 GHz - 18 GHz:	-5 dBm

Counter should display the correct frequency.

d. Connect a 100 nanosecond pulse modulated signal source to the Band B input. Repeat step c above. NOTE: Refer to paragraph 6-3 for pulse width measurement.

7-10. GATE ERROR — BAND A (OPTION P2)

NOTE: Refer to paragraph 3-34 for discussion of gate error.

a. Set SAMPLE RATE control fully counter-clockwise, and BAND SELECT switch to Band A.

b. Apply a 950 MHz CW signal at -10 dBm to the Band A input.

NOTE: Gate error measurements can be made using one of the following two methods:

(1) METHOD 1: Pulse modulates signal source with 100 ns wide pulses; requires use of strip chart recorder and BCD Output (Option P4) on counter.

(2) METHOD 2: Simulates modulation by applying 100 ns wide ENABLE pulses to the INPUT INHIBIT connector on the rear panel of the counter.

(Method 2 is recommended as it avoids errors associated with possible pulling of the signal source.)

c. Using Method 1:

(1) Set up test equipment as shown in Figure 3-7, with recorder connected to the BCD output of the counter.

(2) Record the CW frequency reading.

(3) Pulse modulate — use Method 1 or 2.

(4) Record the average pulse reading.

(5) Gate error is equal to the difference between the reading for (2) and (4). For 100 ns wide pulses, error should be less than 670 kHz.

d. Using Method 2:

(1) Reduce SAMPLE RATE time so each reading can be recorded (on scratch pad or chart).

(2) Record CW frequency reading.

(3) Pulse modulate — use Method 1 or 2.

(4) Record and then average ten or more successive readings.

(5) Gate error is equal to the difference between the readings for (2) and (4). For 100 ns wide pulses, error should be less than 670 kHz.

7-11. GATE ERROR — BAND B

NOTE: Refer to paragraph 3-34 for discussion of gate error.

a. Set SAMPLE RATE control fully counter-clockwise, BAND SELECT to Band B, AUTO SWEEP, and 01.0 GHz START FREQUENCY.

b. Apply a 1.3 GHz CW signal at -10 dBm to the Band B input.

c. Repeat step 7-10c. NOTE: Gate error is a function of IF frequency.

7-12. REAR PANEL OUTPUT LEVELS

a. Apply a pulse modulated signal to the counter.

b. Measure GATE and SIGNAL THRESHOLD outputs using a 50 ohm shunt feedthru to an oscilloscope.

(1) SIGNAL THRESHOLD OUTPUT should be zero VDC with no RF signal, and at least -0.5 VDC when RF is present.

(2) GATE OUTPUT should be at least - 0.5 VDC, corresponding to counter gate.

7-13. REAR PANEL INPUT INHIBIT LEVELS

NOTE: INPUT INHIBIT has a 50 ohm source impedance returned to -2 VDC.

a. Apply a CW signal to the counter.

b. Apply -1.7 VDC to the INPUT INHIBIT connector. Counter should operate normally.

c. Apply - 0.9 VDC to the INPUT INHIBIT connector. Counter should stop counting, and operate as if a no signal condition existed.

SECTION 8

PARTS LISTS

8-1. GENERAL

8-2. This section contains information helpful in ordering replacement parts for this counter. Four tables provide sufficient information for identifying a part and obtaining a replacement, either from EIP or from the manufacturer.

8-3. LIST OF TABLES

a. Table 8-1, REFERENCE DESIGNATORS/ABBREVIATIONS: Lists abbreviations used as schematic reference designators, and in parts list descriptions. Note that some components have two distinct "codes" identifying that part. For example: an integrated circuit is identified on schematics as "U", but in the parts lists as "IC".

b. Table 8-2, LIST OF MANUFACTURERS: Provides a listing of manufacturers names and addresses, and their Federal Supply Code for Manufacturers (FSCM) number. The FSCM number (or an equivalent) is used in the parts lists as the guide to the manufacturer or supplier of the part.

c. Table 8-3, MASTER PARTS LIST: This list has an entry for each separate replaceable part used in the counter. Entries are arranged by EIP Part Number and contain a part description plus the manufacturer's part and FSCM number. This table is used with Table 8-4 to completely identify a component part.

d. Table 8-4, REPLACEABLE PARTS LIST: This table provides a detailed component parts listing for all PC boards and assemblies where the parts or components are field replaceable. NOTE: Certain assemblies cannot be field repaired, but must be returned to EIP for service. This table is arranged first by Assembly number (A101, A102, etc.), then by the schematic reference designator (if any) associated with the assembly. Parts identical to those listed earlier for that assembly are identified in the column headed "SAME". The EIP Part Numbers refer to those referenced in Table 8-3.

8-4. TO ORDER REPLACEMENT PARTS:

a. Send order directly to EIP at the address shown on the title page of this manual.

b. Specify the EIP Part Number, Reference Designator (if any), and a brief description of the part.

c. For parts not listed in the Parts List: Specify the function, location, and description of the part required, and the model and serial number of the counter.

TABLE 8-1.
REFERENCE DESIGNATORS AND ABBREVIATIONS

REFERENCE DESIGNATORS

A	Assembly
B	Battery
C	Capacitor
CR	Diode
DS	Indicator (display)
F	Fuse
J	Jack (receptacle)
K	Relay
L	Inductor
P	Plug or PCB contacts
Q	Transistor
R	Resistor
S	Switch
T	Transformer
TP	Test Point
U	Integrated Circuit
W	Wire (cable)
X	Socket or Holder
Q1-3	Q1 through Q3
Q1/2	Q1 and Q2 (matched pair)

ABBREVIATIONS

CER	Ceramic
CNTR	Counter
CNV	Converter
COMP	Composition
CONN	Connector
DI	Diode
ELEC	Electrolytic
FDTH	Feedthrough
FLTR	Filter
FML	Female
GP	General Purpose
IC	Integrated Circuit
INCN	Interconnection PCB
IND	Inductor
K	Kilo (x 1,000)
LED	Light-emitting diode
M	Meg (x 1,000,000)
MF	Metal Film
ML	Male
MP	Mechanical Part
MTCH PR	Matched Pair
PC	Printed Circuit
PCB	PC Board Assembly
PF	Picofarad
PREC	Precision
RSTR	Resistor
S.A.T.	Value or type selected during factory test. Part may not be used.
SW	Switch
TANT	Tantalum
TRIM	Trimmer
UF	Microfarad
UH	Microhenry
VAR	Variable
WW	Wirewound
XFMR	Transformer
XSTR	Transistor

FSCM	MFR NAME,ADDRESS,ZIPCODE
00809	CROVEN LTD,WHITBY,ONTARIO,CANADA
01121	ALLEN-BRADLEY CO..SO.MILWAUKEE,WI 53204
01295	TEXAS INSTRUMENTS INC..DALLAS,TX 75222
02660	AMPHENOL CONNECTOR DIV..BUNKER RAMO CORP..BROADVIEW,IL 60153
02735	SOLID STATE DIV..RCA CORP..SOMERVILLE,NJ 08876
04009	ARROW-HART INC..HARTFORD,CT 06106
04618	AMERICAN PAMCOR INC..PAOLI,PA 19301
04713	SEMICONDUCTOR DIV..MOTOROLA INC..PHOENIX,AZ 85008
05245	CORCOM INC..CHICAGO,IL 60639
05591	GENERAL RESISTANCE DIV..CHRONETICS INC..MT.VERNON,NY 10550
07263	FAIRCHILD SEMICONDUCTOR, MOUNTAIN VIEW,CA 94040
08717	SLOAN COMPANY,SUN VALLEY,CA 91352
09353	C AND K COMPONENTS INC..WATERTOWN,MA 02172
11236	CTS OF BERNE INC..BERNE,IN 46711
12436	GENERAL DYNAMICS CORP..SAN DIEGO,CA 92112
14298	AMERICAN COMPONENTS INC..CONSHOHOCKEN,PA 19428
14433	ITT SEMICONDUCTOR DIV.OF ITT CORP..W.PALM BEACH,FL 33401
18324	SIGNETICS CORP..SUNNYVALE,CA 94086
18518	MSI ELECTRONICS INC..WOODSIDE,NY 11377
21793	DANA LABORATORIES INC..IRVINE,CA 92664
23880	STANFORD APPLIED ENGINEERING INC..SANTA CLARA,CA 95050
23936	PAMOTOR INC..BURLINGAME,CA 94010
24546	CORNING GLASS WORKS,BRADFORD,PA 16701
26654	VARADYNE INDUSTRIES,SANTA MONICA,CA 90404
27014	NATIONAL SEMICONDUCTOR CORP..SANTA CLARA,CA 95051
28480	HEWLETT-PACKARD CO..PALO ALTO,CA 94304
29990	ATC DIV,PHASE INDUST,HUNTINGTON STATION,NY 11746
50522	ELECTRONIC SPECIAL PRODUCTS,MONSANTO CO..CUPERTINO,CA 95014
56289	SPRAGUE ELECTRIC CO..NORTH ADAMS,MA 01247
70903	BELDEN CORP..CHICAGO,IL 60644
71400	BUSSMAN MFG DIV..MCGRAW-EDISON CO..ST.LOUIS,MO 63107
72136	ELECTRO-MOTIVE MFG. CO..WILLIMANTIC,CT 06226
72259	NYTRONICS INC..PELHAM MANOR,NY 10803
72982	ERIE TECHNOLOGICAL PRODUCTS INC..ERIE,PA 16512
73138	HELIPOT DIV..BECKMAN INSTRUMENTS,FULLERTON,CA 92634
73445	AMPEREX ELECTRONIC CORP..HICKSVILLE,NY 11802
81349	MILITARY SPECIFICATION
86797	ROGAN BROS.INC..SKOKIE,IL 60076
91637	DALE ELECTRONICS INC..COLUMBUS,NE 68601
91836	KINGS ELECTRONICS CO..TUCKAHOE,NY 10707
95275	VITRAMON INC..BRIDGEPORT,CT 06601
98291	SEALECTRO,MAMARONECK,NY 10544
99392	STM CORP..OAKLAND,CA 94601
99800	DELAVAN DIV..AMERICAN PRECISION INDUST..EAST AURORA,NY 14052
	FOLLOWING MFRS DO NOT HAVE FSCM NUMBER
0000A	MOLEX INC..LISLE,IL 60532
0000B	STETTNER-TRUSH,CAZENOVIA,NY 13035
0000C	PLESSEY ELECTRO-PRODUCTS,LOS ANGELES,CA 90066
0000L	R-OHM CORPORATION,IRVINE,CA 92664
0000M	LEMO U.S.A. INC..BERKELEY,CA 94710
0000N	AYER ENGINEERING CO,TUCSON,AZ 85705

TABLE 8-2. LIST OF MANUFACTURERS

EIP P/N	ITEM DESCRIPTION	MFR	MFR PART NUMBER
2020041	PCB:UNIVERSAL EXTENDER	EIP	
2030002	OSC,XTAL: TCXO	EIP	SRCE CONT DWG
2030011	OSC,XTAL: ROOM TEMP	00809	A187DED-30
2040063	ASSY:HARNESS	EIP	451-A110
2040066	ASSY:HARNESS	EIP	451-A204
2040068	ASSY:HARNESS	EIP	451-A200
2040073	ASSY:CABLE,FLT RIBBON	EIP	451-A110
2040090	ASSY:CABLE,FLEX,CO-AX	EIP	451-A103
2040091	ASSY:CABLE,FLEX,CO-AX	EIP	451-A105
2040092	ASSY:CABLE,FLEX,CO-AX	EIP	451-A105
2040095	ASSY:CABLE,FLEX,CO-AX	EIP	451-A200
2040096	ASSY:CABLE,FLEX,CO-AX	EIP	451-A200
2040097	ASSY:CABLE,FLEX,CO-AX	EIP	451-A200
2040098	ASSY:CABLE,FLEX,CO-AX	EIP	451-A200
2040099	ASSY:CABLE,FLEX,CO-AX	EIP	451-A200
2040107	ASSY:CABLE,FLEX,CO-AX	EIP	451-A109
2040112	ASSY:HARNESS	EIP	
2100002	CAP:CHIP .001UF 20% 50V	95275	VJ1210A102MF
2100010	CAP:CHIP 10PF 10% 50V	95275	VY73CA100KF
2100011	CAP:CHIP 10PF 5% 50V	29990	ATC100A100JC50
2150001	CAP:CER .001UF 20% 1KV	56289	5GA-D10
2150003	CAP:CER .01UF 20% 100V	56289	TG-S10
2150006	CAP:CER .02UF 20% 100V	56289	TG-S20
2150007	CAP:CER .005UF 20% 1KV	56289	5GA-D50
2150010	CAP:CER .05UF 20V	73445	UK20-503
2160004	CAP:CER 10PF NPO 500V	72982	301000C0H0100C
2160005	CAP:CER 12PF NPO 500V	72982	301000C0G0120C
2160006	CAP:CER 15PF NPO 500V	72982	301000C0G0150J
2160007	CAP:CER 18PF NPO 500V	72982	301000C0G0180J
2160008	CAP:CER 2.2PF NPO 500V	72982	301000C0J0229C
2160009	CAP:CER 22PF NPO 500V	72982	301000C0G0220J
2160010	CAP:CER 24PF NPO 500V	72982	301000C0G0240J
2160011	CAP:CER 3.0PF NPO 500V	72982	301000C0J0309C
2160012	CAP:CER 3.3PF NPO 500V	72982	301000C0J0339C
2160013	CAP:CER 4.7PF NPO 500V	72982	301000C0H0479C
2160014	CAP:CER 6.8PF NPO 500V	72982	301000C0H0689C
2160016	CAP:CER 20PF NPO 500V	72982	301000C0G0200J
2160999	CAP:CER-SELECT AT TEST	72982	301000C0X0XXXX
2200010	CAP:ELEC 8500UF 25V	99392	91C25HA852
2200012	CAP:ELEC 11000UF 15V	99392	39CS15JP113
2200013	CAP:ELEC 45000UF 15V	0000N	EMC453CG15T
2250001	CAP:MICA 10PF 5% 500V	72136	DM15CD100D0
2250002	CAP:MICA 100PF 5% 500V	72136	DM15CD101JO
2250003	CAP:MICA 1000PF 5% 500V	72136	DM15CD102JO
2250005	CAP:MICA 150PF 5% 500V	72136	DM15CD151JO
2250006	CAP:MICA 180PF 5% 500V	72136	DM15CD181JO
2250008	CAP:MICA 20PF 5% 500V	72136	DM15CD200JO
2250009	CAP:MICA 200PF 5% 500V	72136	DM15CD201JO
2250010	CAP:MICA 22PF 5% 500V	72136	DM15CD220JO
2250012	CAP:MICA 27PF 5% 500V	72136	DM15CD270JO
2250014	CAP:MICA 33PF 5% 500V	72136	DM15CD330JO
2250016	CAP:MICA 39PF 5% 500V	72136	DM15CD390JO
2250017	CAP:MICA 47PF 5% 500V	72136	DM15CD470JO
2250025	CAP:MICA 68PF 5% 500V	72136	DM15CD680JO
2250026	CAP:MICA 680PF 5% 500V	72136	DM15CD681JO
2250027	CAP:MICA 120PF 5% 500V	72136	DM15CD121JO
2250028	CAP:MICA 15PF 5% 500V	72136	DM15CD150JO
2300005	CAP:TANT .47UF 35V	14433	TAG20-0.47/35-50
2300008	CAP:TANT 1.0UF 35V	14433	TAG20-1.0/35-50
2300010	CAP:TANT 10UF 16V	14433	TAG20-10/16-50
2300015	CAP:TANT 33UF 10V	14433	TAG20-33/10-50
2300017	CAP:TANT 47UF 6.3V	14433	TAG20-47/6.3-50
2300020	CAP:TANT .10UF 35V	14433	TAG20-.10/35-50
2300023	CAP:TANT 33UF 20% 20V	14433	TAG20-33/20
2300024	CAP:TANT 100UF 20% 6.3V	14433	TAG20-100/6.3
2300025	CAP:TANT 47UF 20% 16V	14433	TAG20-47/16-20
2350001	CAP:TRIM 2-8PF 250V	0000B	10S-T-22-2/8
2350002	CAP:TRIM 5.5-18PF 250V	0000B	10S-T-22-5.5/18
2350003	CAP:TRIM 8-25PF 250V	0000B	10S-T-22-8/25
2350017	CAP,FDTH:RF FILTER,5KPF	04618	859556-1
2350022	CAP:TRIM 5.5-18PF 250V	0000B	10S-T-24-5.5/18
2350027	CAP:MONO .022UF 10% 50V	26654	2130X7R050R223K
2610010	CONN:JACK,BLKHD,RECPT	98291	51-045-0000
2610017	CONN:PLUG,PC RCPT,STR	98291	52-052-0000
2610018	CONN:JACK,PC RCPT,STR	98291	51-051-0000
2610024	CONN:BNC,BLKHD,TRS FNSH	91836	KC-79-35
2620006	CONN:PC WAFER 6PIN ML	0000A	09-18-5061
2620008	CONN:PC RT AN 5PIN ML	0000A	09-66-1051
2620014	CONN:PC WAFER 4PIN, ML	0000A	09-60-1041
2620016	CONN:PC WAFER, 6PIN, ML	0000A	09-60-1061
2620018	CONN:PC EDGE 18PIN	04618	1-583407-8
2620019	CONN:PC EDGE 8PIN	04618	583407-9
2620029	CONN:PC RT AN,3PIN, ML	0000A	09-66-1031
2620042	CONN:PC WAFER, 9PIN, ML	0000A	09-60-1091
2620044	CONN:PC WAFER,12PIN, ML	0000A	09-60-1121
2620048	CONN:PC RT AN 8PIN ML	0000A	09-66-1081
2630002	SOCKET: 16 PIN,NYLON	0000A	A-4497-16
2630003	SOCKET: 14 PIN,NYLON	0000A	A-4497-14
2640004	CONN 50PIN	02660	57-40500
2640022	CONN:RECPT,6 PIN,ML/FML	0000M	RA1.306NYL
2650003	CONN/FILTER:PANEL MNT	05245	6J4
2700827	DIODE: 6.2V ZENER	04713	1N827
2704001	DIODE: RECT	04713	1N4001
2704154	DIODE: GEN PURP	07263	1N4154

TABLE 8-3. MASTER PARTS LIST

EIP P/N	ITEM DESCRIPTION	MFR	MFR PART NUMBER
2704757	DIODE: 51V ZENER	04713	1N4757
2705227	DIODE: 3.6V ZENER	04713	1N5227
2705230	DIODE: 4.7V ZENER	04713	1N5230
2705231	DIODE: 5.1V ZENER	04713	1N5231
2705234	DIODE: 6.2V ZENER	04713	1N5234
2705237	DIODE: 8.2V ZENER	04713	1N5237
2710004	DIODE: HOT CARR	07263	FH1100
2710006	DIODE: HOT CARR	28480	5082-2800
2710012	DIODE:VOLT VAR CAP	04713	MV109
2710014	DIODE,MTCH PR:FH1100	EIP	2710004
2710016	DIODE: HOT CARRIER	28480	5082-2835
2710028	BRDG RECT	04713	MDA990-1
2710029	BRIDE RECT	04713	MDA970-1
2710030	DIODE,MTCH PR: MV1404	18518	HA116
2710031	DIODE,GRADED:1N960B-01	EIP	2730960
2710032	DIODE,GRADED:1N960B-02	EIP	2730960
2720963	DIODE: 12V ZENER	04713	1N963A
2800001	LAMP,INDICATOR: RED	50522	MV5021
2800004	IC:NUMERIC IND, RED	28480	5082-7730
2800008	LAMP,LED: GREEN	50522	MV5253
2800010	LAMP:LED,5V 15MA,RED	08717	2L5S-RTPFL5/15
2800014	LAMP:LED,YEL DIFFUSED	50522	MV5353
3007400	IC:QUAD 2INP NAND GATE	27014	DM7400N
3007402	IC:QUAD 2INP NOR GATE	27014	DM7402N
3007404	IC:HEX INVERTER	27014	DM7404N
3007405	IC:HEX INVERTER	27014	DM7405N
3007408	IC:QUAD 2INP AND GATE	01295	SN7408N
3007410	IC:TRI 3INP NAND GATE	27014	DM7410N
3007413	IC:DUAL 4INP NAND TRIG	27014	DM7413N
3007420	IC:DUAL 4INP NAND GATE	27014	DM7420N
3007430	IC:8INPUT NAND GATE	27014	DM7430N
3007432	IC:QUAD 2INP OR GATE	27014	DM7432N
3007447	IC:BCD/7SEG DECODER	27014	DM7447N
3007454	IC:4WIDE 2INP AOI GATE	27014	DM7454N
3007473	IC:DUAL J-K F/F	27014	DM7473N
3007475	IC:QUAD LATCH	27014	DM7475N
3007476	IC:DUAL J-K F/F	27014	DM7476N
3007486	IC:QUAD 2INP EXCL OR GT	01295	SN7486N
3007490	IC:DECADE COUNTER	27014	DM7490N
3007493	IC:4BIT BINARY COUNTER	27014	DM7493N
3009602	IC:DUAL TTL/MONOSTBL MV	27014	DM9602N
3010616	IC:UHF COUNTER-DIVIDE/4	000CC	SP8616B
3010637	IC:UHF BCD DEC CNTR	0000C	SP8637B
3011414	IC:DUAL DIFF COMP	04713	MC1414L
3011495	IC:FOUR-QUAD MULTIPLIER	04713	MC1495L
3014044	IC:PHASE/FREQ DETECTOR	04713	MC4044P
3040304	IC:VOLT REG	27014	LM304
3040305	IC:VOLT REG	27014	LM305
3040555	IC:TIMER,LINEAR	18324	NE555V
3040733	IC:DIFF VIDEO AMPL	07263	UA733
3040741	IC:OP AMPL	27014	LM741CN
3041458	IC:OP AMPL	04713	MC1458P1
3043049	IC:DUAL/DIFF AMPL	02735	CA3049T
3043130	IC:OP AMPL: COS/MOS	02735	CA3130S
3050710	IC:VOLT COMPARATOR	27014	LM710CN
3070001	IC:QUAD 2-1 LN DATA SEL	01295	SN74LS257N
3074123	IC:TTL/MONOSTABLE MV	01295	DM74123N
3074155	IC:DUAL 2/4LINE DECODR	27014	DM74155N
3074157	IC:QUAD 2INP MULTIPLEXR	27014	DM74157N
3074176	IC:PRESET DEC COUNTER	27014	DM74176N
3074177	IC:PRESET BINARY CNTR	27014	DM74177N
3074193	IC:UP/DN BINARY CNTR	01295	SN74193N
3074196	IC:PST DECADE COUNTER	01295	SN74196N
3074393	IC:DUAL 4-BIT BIN CNTR	27014	DM74393P
3110104	IC:QUAD 2INP AND GATE	04713	MC10104P
3110105	IC:TRI OR GATE	04713	MC10105L
3110116	IC:TRIPLE LINE RECEIVER	04713	MC10116P
3110125	IC:QUAD TRANSLATOR	04713	MC10125L
3110138	IC:BI-QUINARY COUNTER	04713	MC10138P
3110210	IC:DUAL 3INP/3OUT OR GT	04713	MC10210L
3110216	IC:TRIPLE LINE RCVR	04713	MC10216L
3110231	IC:DUAL D F/F	04713	MC10231L
3112000	IC:DIGITAL MIXER/TRANS	04713	MC12000P
3114050	IC:NON-INVERT HEX BUFFR	04713	MC14050CP
3510001	INDUCTOR: 0.1UH	72259	DD-0.10
3510003	INDUCTOR: 1.0UH	72259	DD-1.00
3510008	INDUCTOR: 0.15UH	99800	1025-00
3510010	INDUCTOR: 1.2UH	99800	1025-22
3510011	INDUCTOR: 0.12UH	72259	DD-0.12
3520007	INDUCTOR: 100 UH	99800	1537-76
4000XXX	RSTR:COMP 5% TOL, 1/8W	81349	RC05GFXXXJ
4000999	RSTR:COMP-SLECT AT TEST	81349	RC05GFXXXJ
4010XXX	RSTR:COMP 5% TOL, 1/4W	81349	RC07GFXXXJ
4010591	RSTR:COMP 5.1 OHMS 5%	81349	RC07GF5R1J
4010596	RSTR:COMP 5.6 OHMS 5%	81349	RC07GF5R6J
4010999	RSTR:COMP-SLECT AT TEST	81349	RC07GFXXXJ
4020XXX	RSTR:COMP 5% TOL, 1/2W	81349	RC20GFXXXJ
4030XXX	RSTR:COMP 5% TOL, 1W	81349	RC32GFXXXJ
	NOTE: RN55- RESISTORS ARE METAL FILM TYPE		
4051212	RSTR:PREC 12.1K OHM 1%	81349	RN55C1212F
4053922	RSTR:PREC 39.9K OHM 1%	81349	RN55C3922F
4057500	RSTR:PREC 750 OHM 1%	81349	RN55C7500F
4061472	RSTR:PREC 14.7K OHM 1%	81349	RN55D1472F

TABLE 8-3 (Continued). MASTER PARTS LIST

EIP P/N	ITEM DESCRIPTION	MFR	MFR PART NUMBER
4062261	RSTR:PREC 2.26K OHM 1%	81349	RN55D2261F
4062431	RSTR:PREC 2.43K OHM 1%	81349	RN55D2431F
4062871	RSTR:PREC 2.87K OHM 1%	81349	RN55D2871F
4064752	RSTR:PREC 47.5K OHM 1%	81349	RN55D4752F
4065621	RSTR:PREC 5.62K OHM 1%	81349	RN55D5621F
4065761	RSTR:PREC 5.76K OHM 1%	81349	RN55D5761F
4068661	RSTR:PREC 8.66K OHM 1%	81349	RN55D8661F
4101003	RSTR:PREC 100K OHM .1%	14298	AME55-C3-10003B
4102003	RSTR:PREC 200K OHM.25%	14298	AME55-C3-2003C
4104003	RSTR:PREC 400K OHM .5%	14298	AME55-C1-4003D
4108002	RSTR:PREC 80K OHM .1%	14298	AME55-C3-8002B
4110003	RSTR:WW 5 OHM 1% 7W	12436	T7(10PPM)
4110004	RSTR:WW 0.5 OHM 3% 2W	91637	RS-2B
4110010	RSTR:WW 30 OHM 5% 1W	56289	239E3005
4110012	RSTR:WW 0.66 OHM 3% 4W	91637	RS-2
4110013	RSTR:WW 0.15 OHM 3% 5W	91637	RS-5
4120008	RSTR:CBN FLM 8.2 OHM 5%	0000L	R25-8.2-5%-1/4W
4120010	RSTR:CMT FLM 1.00MEG 1%	01121	CC1004F
4120011	RSTR:CMT FLM 2.00MEG 1%	01121	CC2004F
4120012	RSTR:CMT FLM 4.02MEG 1%	01121	CC4024F
4130XXX	RSTR:MET OX,100PPM,1/4W	24546	C4/2%/OHMS
4130999	RSTR:MTOX-SLECT AT TEST	24546	C4/2%/XXX
	NOTE: 4S8P- RESISTORS NON-INDUCTIVE WIREWOUND		
4140030	RSTR:PREC 8K OHM .01%	05591	TYPE 4S8P1S8
4140031	RSTR:PREC 10K OHM .01%	05591	TYPE 4S8P1S8
4140032	RSTR:PREC 20K OHM.025%	05591	TYPE 4S8P1S8
4140033	RSTR:PREC 40K OHM .05%	05591	TYPE 4S8P1S8
4140034	RSTR:PREC 3K OHM .1%	05591	TYPE 4S8P1S8
4140035	RSTR:PREC 8K OHM .1%	05591	TYPE 4S8P1S8
4140039	RSTR:PREC 3.7K OHM .1%	05591	TYPE 4S8P1S8
4250003	RSTR:VAR CER 1K OHM	73138	72XWR1K
4250006	RSTR:VAR CER 10K OHM	73138	72XWR10K
4250008	RSTR:VAR CER 100K OHM	73138	72XWR100K
4250009	RSTR:VAR CER 500 OHM	73138	72XWR500
4250011	RSTR:VAR CER 10 OHM	73138	72XWR10
4280009	RSTR:VAR WW 500 OHM	73138	89PR-500
4290001	RSTR:VAR 250K/SPDT SW	11236	EF8078/RVF45
4500008	SWITCH:P/B (PWR IND)	EIP	SRCE CONT DWG
4500010	SWITCH:P/B,7-STATION	EIP	SRCE CONT DWG
4510001	SWITCH:TOG,SPDT,120V,5A	09353	7101H
4510007	SWITCH:TOG,DPDT,125V,3A	04009	83054SQ
4540002	SWITCH,THUMBWHEEL: BCD	23880	900048
4703563	XSTR: NPN	07263	2N3563
4704124	XSTR: NPN GP	04713	2N4124
4704126	XSTR: PNP GP	04713	2N4126
4704401	XSTR: NPN	04713	2N4401
4704416	XSTR: N-CHAN JFET	04713	2N4416
4704959	XSTR: PNP RF	04713	2N4959
4705983	XSTR: NPN PWR	04713	2N5983
4705989	XSTR: NPN PWR	04713	2N5989
4710002	XSTR: PNP PWR	04713	MJE370
4710003	XSTR: NPN PWR	04713	MJE520
4710009	XSTR: PNP	04713	MJE350
4710010	XSTR: PNP RF	04713	MPS-H81
4710011	XSTR:GRADED 2N5179-RED	EIP	4705179
4710012	XSTR:GRADED 2N5179-YEL	EIP	4705179
4710013	XSTR:GRADED 2N5179-GRN	EIP	4705179
4710015	XSTR:MTCH PR,2N5179-YEL	EIP	4710012
4710017	XSTR:NPN RF SW	04713	MMT3960
4710018	XSTR: PNP AMPL	04713	MPS-L51
4710019	XSTR: PNP AMPL	04713	MPS-D55
4710021	XSTR: NPN AMPL	04713	MPS-D05
4710022	XSTR: N-CHAN JFET	01295	TIS73
4710023	XSTR: PNP RF	01295	A5T4261
4710024	XSTR: NPN RF	73445	BFR90
4720002	XSTR: NPN RF	04713	2N3866(MOT)
4900004	TRANSFORMER,POWER	EIP	SPEC.CONT.DWG
5000012	FAN,AXIAL,115VAC	23936	8500
5000055	TILT BAIL	21793	453458
5000056	KNOB:RND W/INSERT .51D	86797	RB67-CML-25SHFT
5000060	KEY,POLARIZING,PCB CONN	04618	530030-1
5000079	FUSE: .750A,SB,3AG,250V	71400	MDL-3/4A
5000101	FUSE: 1.5A,SB,3AG,250V	71400	MDX-1-1/2
5000112	BATTERY CLIP, 1/2"SPCG	83330	1234
5210023	COVER,ENCL: TOP	21793	453453
5210024	COVER,ENCL: BOTTOM	21793	453454
5220003	FOOT,PLASTIC:ENCLOSURE	21793	453457
5440002	LINE CORD SET, 3-COND	70903	17250

TABLE 8-3 (Continued). MASTER PARTS LIST

ASSY A1 COMPONENTS (BASIC COUNTER)

REF	EIP P/N
B1 (FAN)	5000012
SIGNL LAMP	2800010
F1 (115V)	5000101
F1 (230V)	5000079
J1 (PWR MOD)	2650003
J2-5	2610024
J6 (ACC PWR)	2640022
SMPL RT KNOB	5000056
TILT BAIL	5000055
TOP COVER	5210023
BTM COVER	5210024
MTG FOOT	5220003
AC PWR CORD	5440002
S101 (POWER)	4500008
S102-104	4510001
THMBWHL SW	4540002
MAN/AUTO SW	4510007
T1 (PWR XFMR)	4900004

PCB ASSY A100 CNTR INTERCONNECT P/N: 2020070

REF	SAME	EIP P/N
J1-2		2620016
J3		2620044
J4-7		2630003
J8		2620014
R1/S9		4290001
R2		4010332
R3		4010182
R4-9		4010222
S1-8		4500010
S9	R1/S9	
XA101-106		2620018
XA107		2620019
XA108-109		2620018
CONN INSERT		5000060

PCB ASSY A102 COUNT CHAIN CONTROL P/N: 2020072

REF	SAME	EIP P/N
C1		2300008
C2-3		2150001
C4		2250026
C5		2300015
C6-10		2150003
C11		2300010
C12	C6	
C13	C11	
C14	C6	
J1		2630003
Q1-7		4710019
Q8		4710003
Q9		4704126
R1		4010100
R2-5		4010752
R6		4010222
R7		4010223
R8		4010103
R9		4010101
R10-11	R6	
R12-18		4010560
R19-25		4010122
R26-32		4010471
R33		4010102
R34		4010821
R35		4250009
R36		4010181
R37-38	R6	
U1		3007402
U2		3007405
U3		3007404
U4		3007476
U5-6		3040555
U7		3007432
U8		3007447
U9		3007493
U10		3074155
U11		3007400
U12		3007454
U13		3007473

PCB ASSY A103 COUNT CHAIN P/N: 2020073

REF	SAME	EIP P/N
C1-2		2150003
C3		2300010
C4	C1	
C5		2300015
C6	C1	
C7	C5	
C8-15	C1	
CR1		2710016
J1-3		2630003
P2		2040090
Q1		4704126
Q2/Q3		4710015
R1		4010471
R2		4130911
R3		4130332
R4	R1	
R5		4010561
R6		4010161
R7		4010271
U1		3070001
U2-5		3007404
U6-12		3007475
U13		3074157
U14-15	U1	
U16-18		3074176
U19		3007402
U20		3007454
U21-22	U16	
U23		3074196

PCB ASSY A104 CONTROL P/N: 2020074

REF	SAME	EIP P/N
C1		2150003
C2		2300024
C3-12		2150001
C13		2300010
C14	C1	
C15		2300017
C16	C13	
C17-20	C3	
C21		2300015
C22-24	C1	
C25	C21	
C26	C1	
C27	C21	
CR1-17		2704154
Q1		4704124
Q2		4704126
Q3	Q1	
Q4-5	Q2	
Q6-9	Q1	
Q10	Q2	
Q11-12	Q1	
Q13	Q2	
R1		4010222
R2		4010332
R3-4		4010100
R5		4010473
R6	R1	
R7		4010562
R8		4010103
R9	R1	
R10	R7	
R11-16		4010102
R17	R8	
R18-21	R11	
R22	R7	
R23	R1	
R24	R8	
R25	R1	
R26	R2	
R27	R5	
R28	R3	
R29	R1	
R30	R3	
R31	R1	
R32		4010821
R33	R8	
R34	R11	
R35-36	R1	
R37		4010101
R38		4010392
R39-40	R11	
R41	R1	
R42-44	R11	
R45	R8	
R46	R7	
R47	R1	
R48	R8	
R49	R7	
R50		4010272
R51		4010393
U1-2		3007476
U3-4		3074155
U5		3007493
U6-7		3009602
U8		3007490
U9		3007413
U10		3007432
U11		3007400
U12		3007404
U13		3007408
U14		3007405
U15	U12	
U16	U13	
U17	U12	
U18	U10	
U19	U13	
U20	U11	
U21	U10	
U22		3007402

PCB ASSY A105 GATE GENERATOR P/N: 2020075

REF	SAME	EIP P/N
C1-4		2150003
C5		2250027
C6		2250010
C7-13	C1	
C14		2300015
C15-16	C1	
C17		2300010
C18-24	C1	
C25	C14	
CR1-2		2704154
J1-4		2610018
P2		2040091
P3		2040092

TABLE 8-4. REPLACEABLE PARTS LIST

Q1/Q2		4710015
Q3		4710010
Q4		4710012
Q5-7		4704124
Q8		4704126
R1		4010510
R2-3		4010220
R4		4130331
R5		4130181
R6		4130241
R7		4130391
R8	R2	
R9		4010101
R10-11		4010331
R12		4010391
R13	R10	
R14		4010820
R15		4010131
R16		4010471
R17		4010151
R18	R14	
R19	R15	
R20	R16	
R21	R10	
R22	R12	
R23	R10	
R24		4010222
R25	R12	
R26		4010122
R27		4010102
R28		4010182
R29	R26	
R30	R27	
R31	R28	
R32	R10	
R33	R27	
R34	R9	
R35		4010470
R36-37	R12	
R38	R10	
R39	R12	
R40	R10	
R41	R16	
R42	R28	
R43	R26	
R44	R27	
R45	R28	
R46	R24	
R47	R12	
R48	R16	
R49	R26	
R50	R27	
R51	R28	
R52-55	R24	
R56	R26	
R57	R27	
R58	R28	
R59	R12	
R60	R24	
R61	R12	
R62	R16	
R63-64	R24	
R65		4010103
R66	R27	
R67	R10	
R68		4010821
R69	R26	
R70	R12	
R71	R1	
R72	R12	
R73		4010680
R74	R24	
U1		3110210
U2-4		3110105
U5		3007408
U6-7		3007405
U8		3110231
U9		3110125
U10	U8	
U11		3110138
U12		3007476
U13		3007432
U14-16		3007490
U17		3007410
U18-19	U14	

PCB ASSY A106
HIGH FREQUENCY
P/N: 2020076

REF	SAME	EIP P/N
C1-2		2150001
C3-4		2150003
C5		2250001
C6-7	C3	
C8		2300010
C9-10	C3	
C11-12	C1	
C13	(NOT USED)	
C14-15		2300025
C16	C1	
C17	C3	
C18	C1	
C19-25	C3	
C26	C1	
C27-28	C3	
C29	C1	
C30-31	C3	
C32		2300008
C33		2250005
C34	C32	
C35	C3	
C36	C32	
C37	C8	
C38	C32	
C39	C33	
C40	C32	
C41		2250003
C42	C32	
C43	C33	
C44	C32	
C45-46	C1	
C47-49	C3	
C50	C32	
C51	C3	
C52	C8	
C53	C3	
C54	C8	
C55	C3	
C56		2300015
C57	C3	
C58	C1	
C59	C3	
CR1-2		2704154
CR3		2705234
CR4	CR1	
CR5		2705231
CR6/CR7		2710030
CR8-10		2710004
CR11		2710032
CR12		2710031
J1-6		2610018
Q1		4704124
Q2-4		4704126
Q5		4704959
Q6-7		4710017
Q8		4710023
Q9		4710024
Q10-11		4710011
Q12-13	Q1	
Q14		4710022
Q15	Q2	
Q16	Q14	
Q17		4710012
Q18	Q1	
Q19	Q2	
Q20		4710021
Q21	Q6	
R1		4010510
R2		4010392
R3		4130102
R4		4010202
R5		4130120
R6		4010221
R7	R5	
R8		4010331
R9	R3	
R10-11		4010102
R12		4010302
R13		4010272
R14	R1	
R15	R12	
R16	R13	
R17		4010596
R18		4010511
R19-21	R10	
R22	R1	
R23	R12	
R24	R13	
R25		4130202
R26		4130680
R27	R17	
R28		4130430
R29		4130101
R30		4010431
R31	R17	
R32		4130560
R33	R17	
R34	R32	
R35		4130152
R36	R17	
R37	R29	
R38		4000820
R39		4010470
R40	R18	
R41		4010100
R42		4130390
R43	R17	
R44	R42	
R45		4130203
R46		4130180
R47	R3	
R48-50	R45	
R51		4010182
R52-55		4010103
R56		4010681
R57	R6	
R58		4130102
R59		4250011
R60		4130100
R61-62	R45	
R63		4130820
R64	R45	
R65		4130131
R66-67		4130243
R68		4130511
R69	R59	
R70		4130999
R71-72	R45	
R73		4130221
R74		4130750
R75	R45	
R76		4130201
R77		4130821
R78	R76	
R79	R74	
R80		4130999
R81	R77	
R82	R6	
R83		4010151
R84		4130681
R85		4130472
R86		4130561
R87	R65	
R88	R10	
R89		4250008
R90		4130103
R91-92	R3	
R93		4010105
R94	R89	
R95		4010303
R96		4010113
R97		4010104
R98-100	R4	
R101	R3	
R102		4130113
R103-104	R3	
R105	R4	

TABLE 8-4. REPLACEABLE PARTS LIST

R106		4010123
R107	R4	
R108	R17	
R109	R66	
R110		4130123
R111	R85	
R112		4130302
R113		4010391
R114	R93	
R115	R10	
U1-2		3043049
U3		3040741
U4		3010637
U5	U3	
U6		3110216
U7	U3	
U8-10		3043130
U11	U3	

PCB ASSY A107
POWER SUPPLY
P/N: 2020077-01

REF	SAME	EIP P/N
C1		2200010
C2		2300010
C3		2250017
C4	C2	
C5		2200013
C6	C2	
C7		2250009
C8		2300025
C9	C2	
C10		2300008
C11		2150001
C12	C1	
C13	C2	
C14	C10	
C15	C11	
C16	C2	
C17		2200012
CR1-4		2704001
CR5		2710028
CR6		2710029
CR7-8	CR1	
CR9		2720963
CR10-11	CR1	
CR12	CR9	
J1		2620006
Q1		4710002
Q2		4705983
Q3	Q1	
Q4		4705989
Q5		4704126
Q6	Q1	
Q7	Q2	
Q8	Q5	
Q9	Q1	
Q10	Q2	
R1		4010680
R2		4130240
R3		4130821
R4		4110012
R5	R3	
R6		4061472
R7		4250009
R8		4062261
R9		4020430
R10	R1	
R11		4130200
R12		4130101
R13		4110013
R14		4065621
R15	R7	
R16		4062871
R17		4130123
R18	R4	
R19		4130911
R20		4065761
R21		4250003
R22		4062431
R23	R1	
R24		4010101
R25		4010102
R26		4130512
R27		4110004
R28	R19	
R29		4010911
R30	R22	
R31	R7	
R32	R22	
R33	R1	
R34	R24	
R35	R25	
U1-2		3040305
U3-4		3040304

PCB ASSY A108
REF.OSC. BUFFER
P/N: 2020078

* INDICATES OPTION P1 (TCXO) VALUES.

REF	SAME	EIP P/N
C1-2		2150003
C3		2250002
C4		2169999
C5		2350001
C6-10	C1	
C11	(NOT USED)	
C12-21	C1	
C22		2250014
C23-31	C1	
C32		2300015
C33	C1	
C34		2300010
C35-36	C1	
C37	C34	
CR1-4		2704154
J1		2620029
Q1-3		4703563
Q4		4710010
Q5	Q1	
Q6		4704126
Q7		4710011
Q8-9	Q1	
Q10	Q4	
Q11	Q7	
Q12-13	Q1	
Q14	Q4	
R1		4130999
R2-3		4130102
R4		4010105
R5-6		4010332
R7-8	R2	
R9		4010102
R10		4010596
R11		4010999
R12		4010100
R13		4130822
R14		4130392
R15		4130681
R16		4130391
R17		4130912
R18	R13	
R19		4130751
R20		4130181
R21	R17	
R22	R13	
R23		4130270
R24		4130301
R25	R12	
R26		4130113
R26*		4130912
R27		4130132
R27*		4130222
R28		4130621
R29		4130101
R29*		4130361
R30		4130431
R31		4130911
R32	R12	
R33	R13	
R34		4130432
R35	R15	
R36		4130561
R37	R12	
R38		4130112
R39-40		4010591
R41	R12	
R42	R13	
R43	R34	
R44	R15	
R45	R36	
R46	R12	
R47	R38	
R48-49	R39	
U1		3110116
Y1		2030011
Y2*		2030002

PCB ASSY A109
PRESCALER - OPTION P2
P/N: 2020079

REF	SAME	EIP P/N
C1-5		2150003
C6		2100010
C7		2100002
C8		2160004
C9-10		2160014
C11		2160016
C12-14	C7	
C15		2100011
C16-23	C7	
C24		2250009
C25-27	C1	
C28		2300010
C29	C1	
C30		2300015
C31	C1	
C32	C28	
C33	C1	
C34	C30	
C35	C1	
C36	C7	
CR1-2		2710016
J1-6		2610018
P2		2040107
Q1-2		4710012
Q3-4		4710024
Q5		4710017
Q6-7		4704126
Q8-9		4704124
Q10		4710002
R1		4130820
R2		4130131
R3		4010202
R4		4010391
R5	R3	
R6		4130221
R7		4130332
R8		4010431
R9		4130102
R10		4130681
R11-12	R4	
R13		4130101
R14-15	R6	
R16		4130132
R17-18	R4	
R19		4130821
R20		4130201
R21		4130912
R22	R9	
R23	R10	
R24		4130181
R25		4130510
R26		4130302
R27		4130911

TABLE 8-4. REPLACEABLE PARTS LIST

R28	R10	
R29		4130240
R30		4130431
R31		4130471
R32		4130161
R33	R16	
R34		4010153
R35-36		4130621
R37		4130271
R38		4130361
R39	R10	
R40		4130202
R41		4130392
R42		4010102
R43		4130752
R44		4130472
R45-46		4010471
R47		4010432
R48		4010362
U1		3110216
U2		3110104
U3		3010616

PCB ASSY A110
DISPLAY
P/N: 2020080

REF	SAME	EIP P/N
DS1-7		2800004
DS8		2800001
DS9-11		2800008
DS12		2800014
J1		2040073
P1		2040063
R1-5		4010151

PCB ASSY A111
BCD OUTPUT/REMOTE
PROGRAMMING - OPT P4
P/N: 2020082

REF	SAME	EIP P/N
C1-3		2150003
CR1-2		2704154
J1-6		2630003
P1		2640004
R1-5		4010222
R6		4010103
R7		4010224
R8		4010104
R9	R6	
R10-20	R1	
R21		4010151
R22		4010101
R23-33	R1	
U1-5		3114050
U6-9		3074157

ASSY A2 COMPONENTS
(CONVERTER TRAY)

REF	EIP P/N
A2Q1	4710009

PCB ASSY A200
CONVERTER INTRCONN
P/N: 2020090

REF	SAME	EIP P/N
J1		2620014
J2		2620042
P1		2040068
P2		2040095
P3		2040096
P4		2040097
P5		2040098
P6		2040099
XA202-203		2620018
CONN INSERT		5000060

PCB ASSY A201
SOURCE/AMPLIFIER
(PART OF MODULE
ASSY 2010091)

REF	SAME	EIP P/N
C1-2		2150003
C3		2300008
C4		2300015
C5-10	C1	
C11		2160016
C12		2160007
C13-15	C1	
C16		2350003
C17		2160013
C18		2160006
C19	C1	
C20		2250005
C21	C1	
C22		2160005
C23		2350001
C24		2160008
C25		2160004
C26-28	C1	
C29-30	C22	
C31	C11	
C32	C1	
C33-34		2150001
C35	C16	
C36	C17	
C37	C18	
C38	C1	
C39		2250002
C40		2350002
C41-42		2160010
C43-44	C1	
C45	C40	
C46	C41	
C47-49	C1	
C50	C39	
C51	C1	
C52	C40	
C53	C41	
C54-55	C1	
C56		2350022
C57-58	C39	
C59-61	C1	
C62		2300010
C63		2150006
C64-66	C1	
C67		2250014
C68	(NOT USED)	
C69-79	C1	
CR1		2710006
CR2		2704154
CR3		2710012
CR4	CR2	
CR5	CR1	
CR6-11	CR2	
FL1-4		2350017
J1-3		2610010
L1-2	(NOT USED)	
L3		3520007
L4		3510003
L5-6	(P/O PCB)	
L7	L4	
L8-9	(P/O PCB)	
L10		3510010
L11		3510001
L12	L4	
L13		(P/O PCB)
L14-15	L10	
L16	L4	
L17	(P/O PCB)	
L18-21	L10	
L22		3510011
L23	L4	
L24-33	L10	
P1		2040112
Q1-2		4704124
Q3		4710012
Q4		4710010
Q5	Q3	
Q6-7		4704416
Q8	Q3	
Q9	Q4	
Q10		4704126
Q11		4710013
Q12	Q6	
Q13-14	Q3	
Q15-16		4720002
Q17		4710003
Q18-21	Q10	
Q22	Q1	
R1		4010202
R2		4010510
R3		4130682
R4		4130392
R5		4130271
R6		4130202
R7	R4	
R8	R3	
R9-11		4010511
R12		4010391
R13		4010111
R14		4130241
R15		4130182
R16		4130122
R17-18		4130622
R19		4130562
R20		4130912
R21		4130302
R22	R16	
R23		4130821
R24		4130102
R25		4010102
R26		4010472
R27		4130511
R28		4130221
R29	R27	
R30	R15	
R31	R28	
R32		4130332
R33		4130243
R34		4010243
R35	R33	
R36	R24	
R37		4130113
R38		4010393
R39		4130201
R40	R24	
R41	R20	
R42	R21	
R43	R16	
R44	R23	
R45	R24	
R46	R4	
R47	R21	
R48	R39	
R49		4130300
R50		4130200
R51	R17	
R52	R24	
R53	R33	
R54	(NOT USED)	
R55		4010561
R56	R2	
R57-58	R17	
R59	R24	
R60		4130223
R61	R24	
R62		4130103

TABLE 8-4. REPLACEABLE PARTS LIST

R63	R37	
R64	R23	
R65		4130272
R66		4010272
R67		4130472
R68		4130391
R69	R32	
R70		4010101
R71		4010103
R72-78	R70	
R79		4130471
R80-81		4130222
U1		3112000
U2		3110138
U3		3014044
U4-5		3040741

PCB ASSY A202
YIG CONTROL
P/N: 2020092

REF	SAME	EIP P/N
C1-2		2150010
C3		2150003
C4-6	C3	
C7		2150007
C8		2150001
C9-11	C3	
C12		2250003
C13		2150006
C14		2300010
C15-18	C3	
C19	C8	
C20		2300020
C21	C3	
C22		2300008
C23	C8	
C24		2250006
C25-26		2250014
C27-28	C14	
C29		2300023
C30-32	C3	
C33		2300015
C34	C3	
C35	C33	
C36-39	C3	
C40	C29	
C41	C3	
CR1		2705231
CR2		2704154
CR3		2700827
CR4	CR2	
CR5		2704757
CR6		2704001
CR7-8	CR2	
J1-2		2630003
J3		2620048
Q1		4704124
Q2-10		4704401
Q11	Q1	
Q12		4710018
Q13	(NOT USED)	
Q14-15	Q1	
Q16		4704126
Q17	Q1	
Q18		4710009
Q19	Q16	
Q20		4710003
R1-2		4130103
R3-4		4130222
R5		4130302
R6		4130752
R7-8		4130113
R9	R5	
R10-11	R3	
R12-15	R1	
R16-17		4130203
R18		4010682
R19		4010133
R20		4010513
R21		4010112
R22		4010101
R23		4010242
R24		4010911
R25		4010222
R26		4010473
R27-28		4010102
R29	R26	
R30	R24	
R31	R23	
R32	R22	
R33		4010103
R34		4010104
R35		4010362
R36	R25	
R37		4010333
R38	R25	
R39	R27	
R40	R25	
R41		4010201
R42		4120010
R43		4120011
R44		4120012
R45		4010825
R46		4010166
R47		4010336
R48		4010626
R49-55		4010272
R56		4010271
R57		4010512
R58	R25	
R59	R49	
R60		4104003
R61	R33	
R62	R49	
R63		4102003
R64	R33	
R65	R49	
R66		4101003
R67	R33	
R68	R49	
R69		4108002
R70	R33	
R71	R49	
R72		4140033
R73		4010123
R74	R49	
R75		4140032
R76		4010203
R77	R49	
R78		4140031
R79	R25	
R80		4140030
R81		4057500
R82-83		4140035
R84		4010152
R85		4140034
R86		4140039
R87		4280009
R88		4051212
R89		4250003
R90		4053922
R91	R85	
R92		4110003
R93		4010162
R94-95		4010391
R96	R27	
R97-104	R25	
R105		4010752
R106		4010153
R107		4020100
R108		4010432
R109		4010511
R110	R106	
R111		4010392
R112	R7	
R113-114		4130181
R115	R7	
R116		4010121
R117		4110010
R118-119	R107	
R120	R116	
R121	R117	
R122		4010304
U1		3011495
U2-3		3040741
U4		3007493
U5		3011414
U6		3007400
U7		3007402
U8		3007404
U9-10		3074193
U11-14	U2	
U15	U8	
U16		3007430
U17-18		3007486
U19-20		3074176

PCB ASSY A203
CONVERTER SEQUENCER
P/N: 2020093

REF	SAME	EIP P/N
C1		2150003
C2		2350027
C3	C1	
C4	C2	
C5-6	C1	
C7		2300005
C8-9	C1	
C10		2300010
C11		2300008
C12		2300015
C13-14	C1	
C15		2250014
C16	C7	
C17	C1	
C18	C12	
C19		2250003
C20-22	C1	
C23	C10	
C24	C1	
C25	C12	
C26-27	C1	
C28	C12	
C29	C1	
C30	C10	
CR1-2		2704154
CR3		2710004
CR4		2705230
CR5		2705237
CR6		2704001
CR7	CR1	
CR8		2705227
CR9		2705231
CR10	CR4	
CR11	CR1	
J1		2620008
Q1-2		4704124
Q3		4704126
Q4	Q1	
Q5-6	Q3	
R1		4010201
R2		4010123
R3-6		4010512
R7		4010102
R8		4010152
R9		4010624
R10		4010334
R11		4010164
R12		4010753
R13		4010393
R14		4130183
R15		4010222
R16		4010822
R17		4130273
R18		4010434

R19		4130103
R20	R7	
R21		4250006
R22		4130512
R23		4130122
R24		4130152
R25		4010104
R26		4010471
R27		4030820
R28		4010103
R29	R19	
R30		4130222
R31	R19	
R32	R16	
R33		4010101
R34		4010163
R35		4010596
R36	R16	
R37		4010473
R38	R34	
R39		4130153
R40	R23	
R41		4130102
R42		4068661
R43		4130912
R44		4250003
R45		4130431
R46		4130271
R47		4130182
R48	R26	
R49		4010202
R50		4130240
R51		4010390
R52	R47	
R53		4130203
R54		4130243
R55		4010472
R56		4010562
R57	R55	
R58		4010622
R59-60	R26	
R61	R7	
R62	R55	
R63	R26	
R64		4010242
R65		4010333
R66	R55	
R67-68	R47	
R69		4010392
R70-73	R3	
R74		4130822
R75	R14	
R76		4010363
R77	R12	
R78	R11	
R79	R10	
R80	R9	
R81		4010999
R82		4010221
R83		4130133
R84		4130472
R85		4130561
R86		4130999
R87		4130272
R88		4010362
R89		4010181
R90	R21	
R91		4010302
R92	R65	
R93	R17	
R94	R24	
R95	R26	
U1		3110125
U2		3007402
U3		3074123
U4		3074393
U5-6		3041458
U7		3007432
U8		3074177
U9		3007400
U10		3074155
U11		3009602
U12	U9	
U13		3007420
U14		3007408
U15	U9	
U16-17		3043130
U18		3040555
U19	U4	
U20	U5	

PCB ASSY A204
IF PROCESSOR (PART OF MODULE ASSY 2010094)

REF	SAME	EIP P/N
C1-2		2250012
C3-4		2150003
C5		2150001
C6-7	C3	
C8		2250028
C9-10	C3	
C11	C5	
C12-13	C3	
C14	C8	
C15	C3	
C16	C5	
C17-18	C3	
C19	C8	
C20	C5	
C21		2250001
C22	C5	
C23	C3	
C24	C5	
C25		2160012
C26-27	C5	
C28	C21	
C29	C5	
C30	C3	
C31	C5	
C32		2250017
C33	(NOT USED)	
C34	C5	
C35		2160014
C36		2300015
C37	C3	
C38		2300010
C39	C36	
C40-41	C38	
C42-43		2300005
C44	C38	
C45	C5	
C46	C21	
C47	C5	
C48	C3	
C49	(NOT USED)	
C50	C5	
C51-53		2160009
C54		2160011
C55	C5	
C56	C35	
C57		2160007
C58		2160013
C59	C35	
C60	C58	
C61		2250025
C62-63	C3	
C64		2250008
C65-66		2250027
C67	C3	
C68-69		2250016
C70-72	C3	
C73	C38	
C74	C3	
C75	C38	
C76	C3	
C77	C36	
C78-79	C5	
CR1-2		2710016
CR3-4		2705234
CR5/CR6		2710014
FL1-3		2350017
J1-7		2610010
J8		2610017
L1-2		3510001
L3-9	(P/O PCB)	
L10-11		3510010
L12		3510008
L13-16	(P/O PCB)	
L17-19		3510011
L20-21	(P/O PCB)	
P1		2040066
Q1-4		4710011
Q5-10		4710023
Q11		4710012
Q12		4704124
Q13		4704126
Q14-15	Q5	
Q16-17	Q1	
Q18		4710010
Q19-20	Q1	
Q21-22	Q18	
R1		4130132
R2		4130201
R3		4130621
R4		4130560
R5		4130242
R6		4010596
R7	R3	
R8		4130911
R9	(NOT USED)	
R10-11		4120008
R12	R4	
R13	R5	
R14	R6	
R15	R3	
R16	R8	
R17-18	R10	
R19	R4	
R20	R5	
R21-23	R6	
R24	R3	
R25	R8	
R26	(NOT USED)	
R27-28	R10	
R29		4010510
R30		4010470
R31		4130271
R32		4130122
R33		4010100
R34		4130121
R35		4130910
R36		4130821
R37	R6	
R38	R29	
R39	R30	
R40	R31	
R41	R32	
R42	R33	
R43	R34	
R44	R35	
R45	R36	
R46	R6	
R47		4130471
R48		4250003
R49	R47	
R50		4010334
R51		4250006
R52		4020161
R53	R6	
R54		4130101
R55		4130162
R56		4130751
R57	R52	
R58	R5	
R59-60	R54	
R61		4130102
R62		4130241
R63		4010181
R64-65		4010432
R66		4010431
R67		4010133
R68-69		4010101
R70		4010621
R71	R68	
R72		4010102
R73	R63	

TABLE 8-4. REPLACEABLE PARTS LIST

R74		4130510
R75	R33	
R76	R32	
R77	R31	
R78	R30	
R79		4130331
R80	(NOT USED)	
R81		4010821
R82	R6	
R83-84		4130470
R85		4010332
R86	R30	
R87	R85	
R88		4010103
R89	R4	
R90		4130103
R91		4064752
R92	R4	
R93	R90	
R94	R91	
R95	R51	
R96		4130183
R97	R1	
R98		4130152
R99		4010472
R100		4010391
R101	R61	
R102-103	R72	
R104		4010200
R105	R100	
R106	R72	
R107	R61	
R108-109	R72	
R110	R100	
R111		4010221
R112		4010111
R113	R68	
R114-115	R88	
R116		4010753
R117	(NOT USED)	
R118		4010104
R119	R88	
R120		4130301
R121	R36	
R122	R72	
R123		4010820
R124		4010131
R125		4130202
R126	R34	
R127		4010390
U1		3040733
U2		3050710
U3-4		3110105
U5	U2	

ASSY A205
MIXER
P/N: 2010007

(NO REPLACEABLE COMPONENTS)

ASSY A206
LIMITER/ATTENUATOR
P/N: 2010096

(NO REPLACEABLE COMPONENTS)

ASSY A207
YIG COMB GENERATOR
P/N: 2010097

(NO REPLACEABLE COMPONENTS)

SECTION 9

CIRCUIT SCHEMATICS & DESCRIPTIONS

COMPONENT LOCATORS

9-1. GENERAL

9-2. Schematics and Component Locators are arranged by Assembly number (A101, A102, etc.). Circuit descriptions and circuit theory are shown on the same or adjacent pages. All assembly related drawings and diagrams have the same figure number, but have different suffix letters (9-6A, 9-6B, etc.).

9-3. Parts Lists and Ordering Information will be found in Section 8.

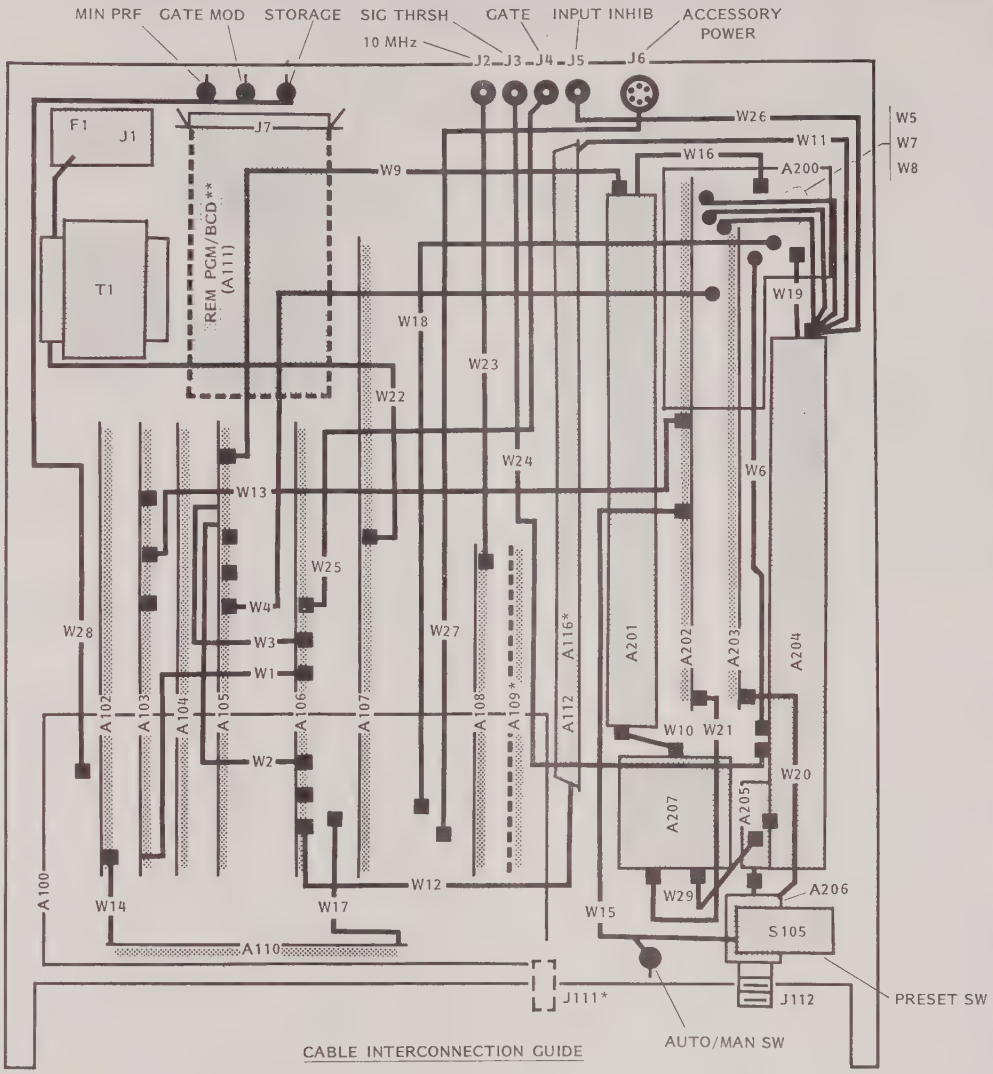
9-4. Unless otherwise specified, the following notes apply to all figures in this section.

a. Resistance values in ohms.

b. Capacitance values in microfarads ("pf" values in picofarads).

c. Connector reference numbers may not appear on part.

d. SAT = Selected at Test. Nominal value shown; part may not be installed. MP = Matched Pair.



CABLE INTERCONNECTION GUIDE

FROM	CABLE	TO
A103-P2	W1	A106-J5
A105-P2	W2	A106-J1
A105-P3	W3	A106 J4
A200-P2	W4	A105-J1
A200-P3	W5	A204-J6
A200-P4	W6	A204-J2
A200-P5	W7	A204-J7
A200-P6	W8	A204-J4
A201-J1	W9	A105-J4
A201-J2	W10	A207-J2
A112-P1	W11	A204-J3
A112 P2	W12	A106 J3
A103-J3	W13	A202-J2
A110-P2	W14	A102-J1
A1-P121	W15	A202-J1**
A201-P1	W16	A200 J2
A110-P1	W17	A100 J2
A200 P1	W18	A100-J3
A204 P1	W19	A200-J1

FROM	CABLE	TO
A206-P2	W20	A203-J1
A202-J3	W21	A1-Q1
		A107-J3
A1 (T1) P101	W22	A107-J1
A1 (J2) P102	W23	A108-J1
A1 (J3) P103	W24	A204-J1*
A1 (J4) P104	W25	A106-J6
A1 (J5) P105	W26	A204-J5*
A1 (J6) P106	W27	A100-J8
A1-P107	W28	A100-J1
A205-P1	W29	A207-J1

DANA EIP

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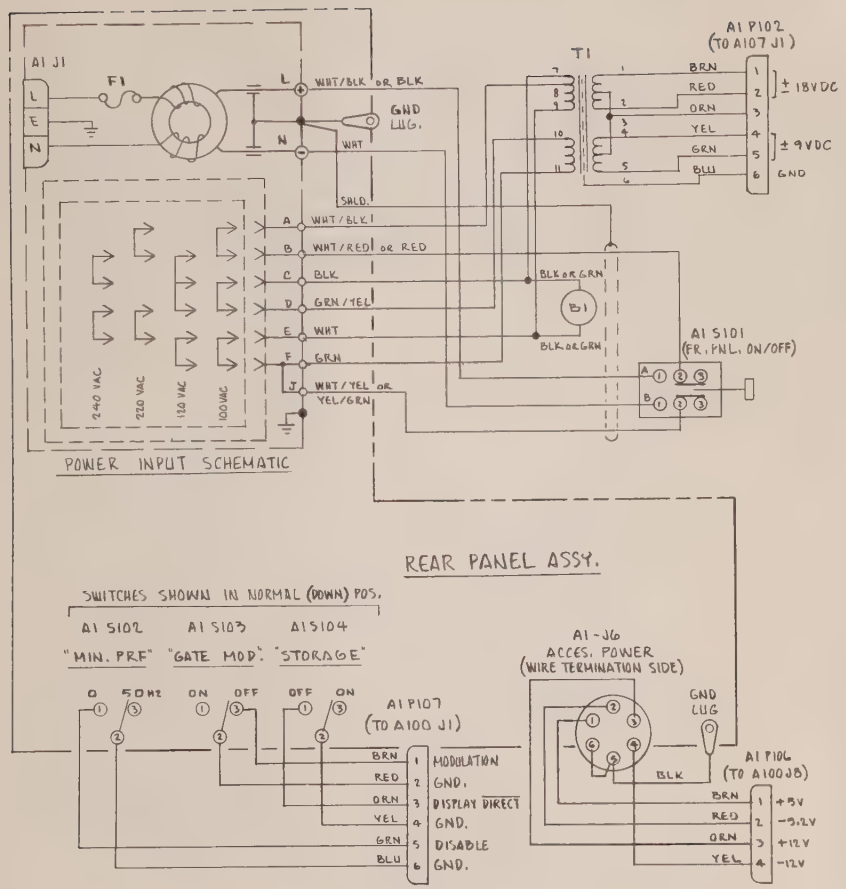
*PRESCALER OPT. P2 A109, A116)

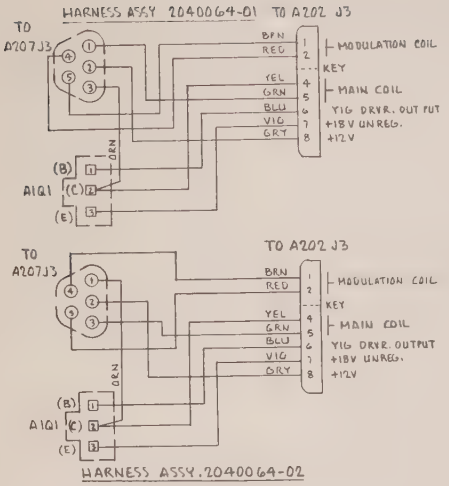
FROM	CABLE	TO
A1-P103	W24	A109-J6
A1-P105	W26	A109-J3
A1-J111	W30	A109-J1
A204-J1	W31	A109-J5
A204-J5	W32	A109-J4
A105-J2	W33	A109-P2
A116-P1	W34	A109-J2
A116-P2	W35	A106-J2

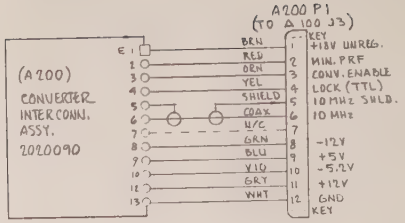
**REM PGM/BCD OUT OPT. P4 (A111)

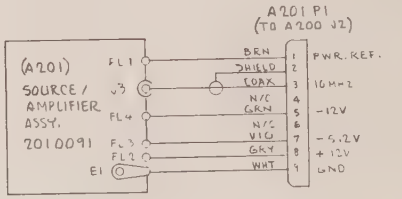
FROM	CABLE	TO
A1-P121	W15	A100-J6
A111-J1	W40	A100-J4
A111-J2	W41	A100-J5
A111-J3	W41	A100-J6
A111-J4	W42	A202-J1
A111-J5	W43	A103-J5
A111-J6	W44	A103-J1

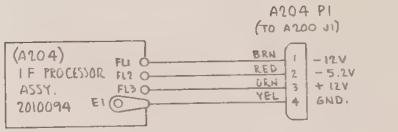
FIGURE 9-1
ASSEMBLY LOCATOR
CABLE INTERCONNECTIONS

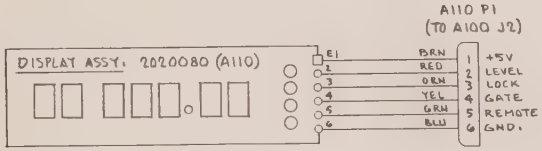












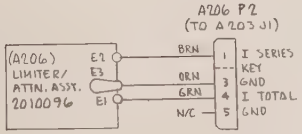


FIGURE 9-2
INTERCONNECTION
DIAGRAM

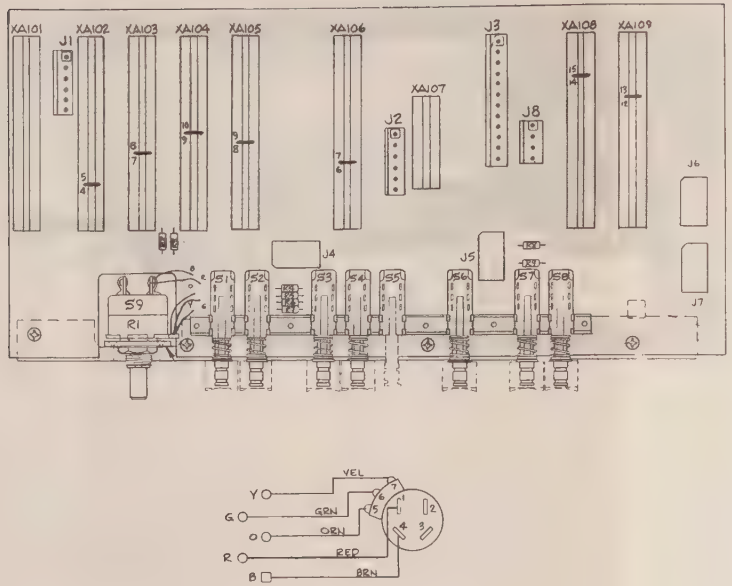


FIGURE 9-3A
COMPONENT LOCATOR
COUNTER INTERCONNECT (A100)

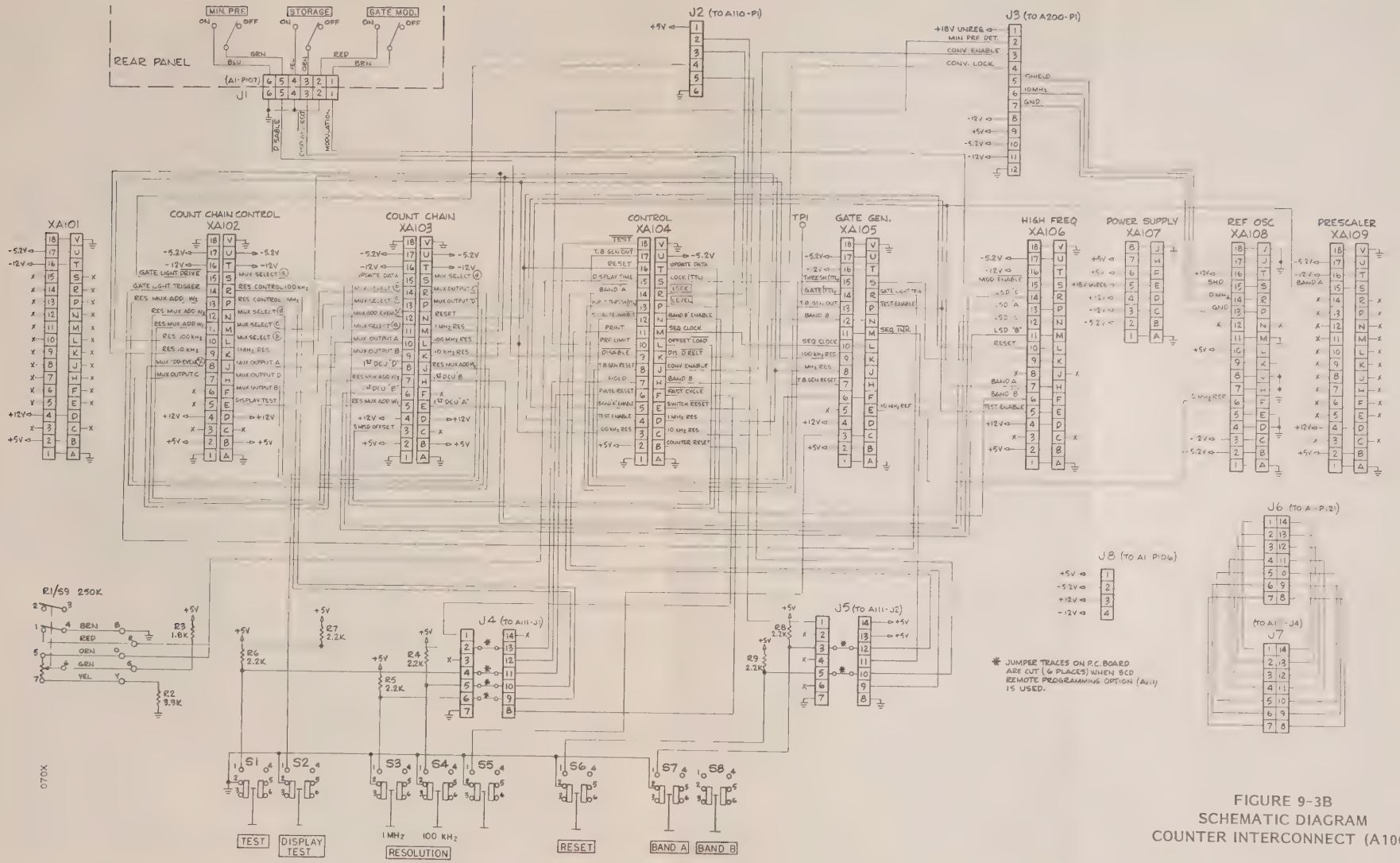
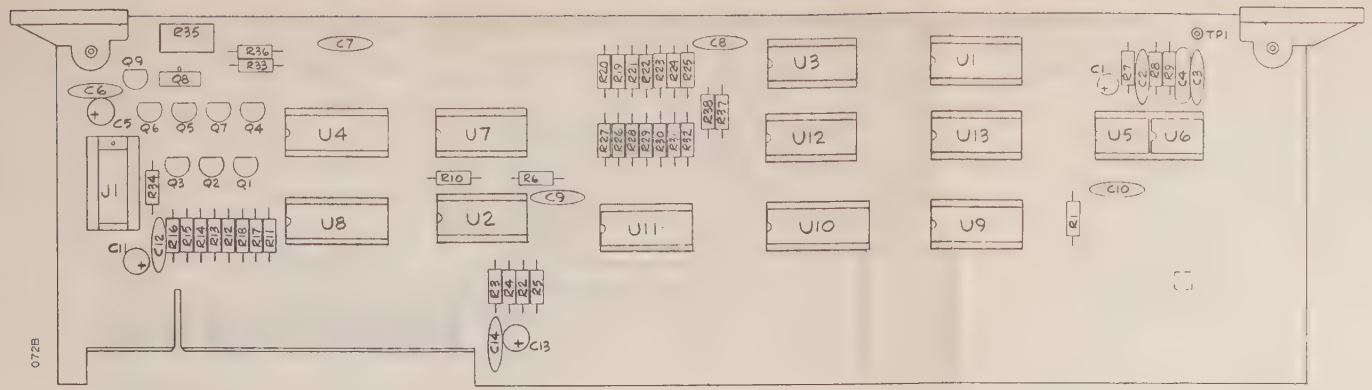


FIGURE 9-3B
SCHEMATIC DIAGRAM
COUNTER INTERCONNECT (A100)



COUNT CHAIN CONTROL (A102)

General

Count Chain Control A102 controls and processes the flow of information on Count Chain board A103, and drives the front panel visual display. A pulse-stretcher and driver (on A102) also operate the GATE indicator on the front panel of the counter.

The clock generator, a ÷16 counter, and a 3-8 line decoder, serve to produce a sequence of eight addresses. These cause the DCU's on Count Chain A103 to read out their BCD contents in sequence back to the data input of A102. The digits of the number representing the frequency measured by the counter are thus read in sequence into A102. The BCD numbers are decoded by U8 to drive the segments of each display digit on Display board A110. The same address generator that selected DCU's on A113 now addresses and drives the proper display digit of A110, so the number of a particular DCU of A103 will be displayed in the proper position. The address drive to certain display digits may be removed to blank these digits (via the RESOLUTION switches).

The main address generator also drives the Resolution Multiplex Address Generator which may shift the positions of data in the Count Chain A103 data latches when the RESOLUTION switches are changed.

The gate trigger is applied to a pulse-stretcher on A102. This insures that the gate control signal is of sufficient duration that the GATE indicator will produce a visible flash for each measurement cycle of the counter. (Short gates would not otherwise be visible.)

Display Address Generator (U6, U9-11)

The Address Generator is driven by the clock generated in U6 at a 200 kHz rate. This drives binary counter U9, producing a sequence of sixteen different states on its four output lines. The last three lines: B, C, and D, drive decoder U10 which produces an output on one of eight output lines for each of the eight different states of the inputs: B, C, and D. The narrow negative clock pulse driving binary counter U9 is also applied via a U1 gate to the gate inputs of decoder U10. This cuts off all outputs of U10 for a short time after each clock input to U9, allowing U9 outputs to come to equilibrium, and insuring only one output from U10 during each clock period.

Seven of the eight single line outputs of decoder U10 are used to select display digits directly. The address to the DCU's of A103 however, is a one-of-four line code, plus an odd-even code on a fifth line. The one-of-four line code is obtained by combining successive outputs of decoder U10 in groups of two in the four NAND gates of U11. The odd-even code is simply the A input to decoder U10.

Display Decoder, Driver and Leading Zero Suppression Circuits (U2, U4, U8)

The BCD to 7-segment decoder is included in U8. It directly supplies the cathode currents to the segments of the display digits which must be illuminated to display the number given by the BCD code. Additional inputs to U8 allow all outputs to be activated simultaneously (Lamp Test which displays all 8's), all outputs turned off simultaneously (BI/RBO which blanks the display), or the output blanked if the BCD input is a zero (RBI); this last input is used in leading zero suppression.

The anode currents of the seven display digits are supplied by the seven individual digit drivers Q1-Q7. These drivers are turned on in sequence by outputs 1 through 7 of decoder U10, and effectively apply the +5 volt adjustable supply to the anodes of the display digits. The segment currents are then determined by the segment drive outputs of U8 and the seven resistors in the output lines (active outputs are driven to ground so that output currents are determined by the value of the series resistors). Corresponding segments of all display digits are wired in parallel; all seven display digits being driven simultaneously by the 7-line decoder. Only one of these digits is supplied anode current by the digit drivers at any given time. The correct BCD input to U8 is selected by address decoders on the Count Chain (A103).

The zero suppression circuits cause all digits to the left of the first non-zero display digit to be blanked. Outputs of decoder U10 are processed in U2, U4, U7, and U8, to produce this result.

Decoder outputs of U10 occur in regular time sequence 0 through 7. Defining the interval in which output 0 is active as TF0 (Time Frame 0), then intervals TF0, TF1..... TF7, are of equal length, and occur in a regular repetitive sequence. Display digits are driven in Time Frames TF1 through TF7. The zero-suppression latches are reset in TF0 of each sequence. The BCD output from A103 is coded to be always zero in TF0. This is decoded in data-detector U2 to produce a high at the set input to U4B latch. U9A output and U10 TF0 output are combined in U3 and U7 to produce a reset input to U4B at TF½ (second half of TF0). U4B is then always reset at the beginning of TF1-TF7 sequence. During this sequence, the DCU outputs of A103 are addressed and read out in sequence: 10 GHz, 1 GHz.. ..100 kHz. If any of these BCD outputs are non-zero, the detector U2 immediately sets U4B. U4B is then reset until the left-most non-zero digit of the display appears, after which it remains set through the rest of each display sequence. This flip-flop is used to remove the suppression where all digits are zero, otherwise the display would disappear completely if there were no input to the counter (zero frequency).

Flip-flop U4A controls the zero suppression directly. If U4B is in set state at the end of a display sequence, then U4A is reset by the clock pulse at TF½ of the next sequence. If U4B is in reset state at the end of TF7, then U4A is set at TF½ of the next sequence. If non-zero data occurs in a display sequence, U4A is set and enables zero suppression in the next sequence. If all data is zero through a sequence, U4A is set and disables zero suppression in the next sequence. Assuming that many display sequences occur for each set of BCD data, then all zero data receives no suppression and all zeros are displayed, while non-zero data has leading zeros suppressed.

U4A enables zero suppression in its reset state by applying the low Q output to the ripple blanking RBI input of U8. With this input low, all decoder outputs are shut off when the data input is low and the BI/RBO output is also low. Whenever data becomes non-zero, BI/RBO goes high and sets U4A, removing the RBI input enable. This can only be enabled again at the start of a following sequence when U4A may be reset.

Resolution Multiplex Address Generator

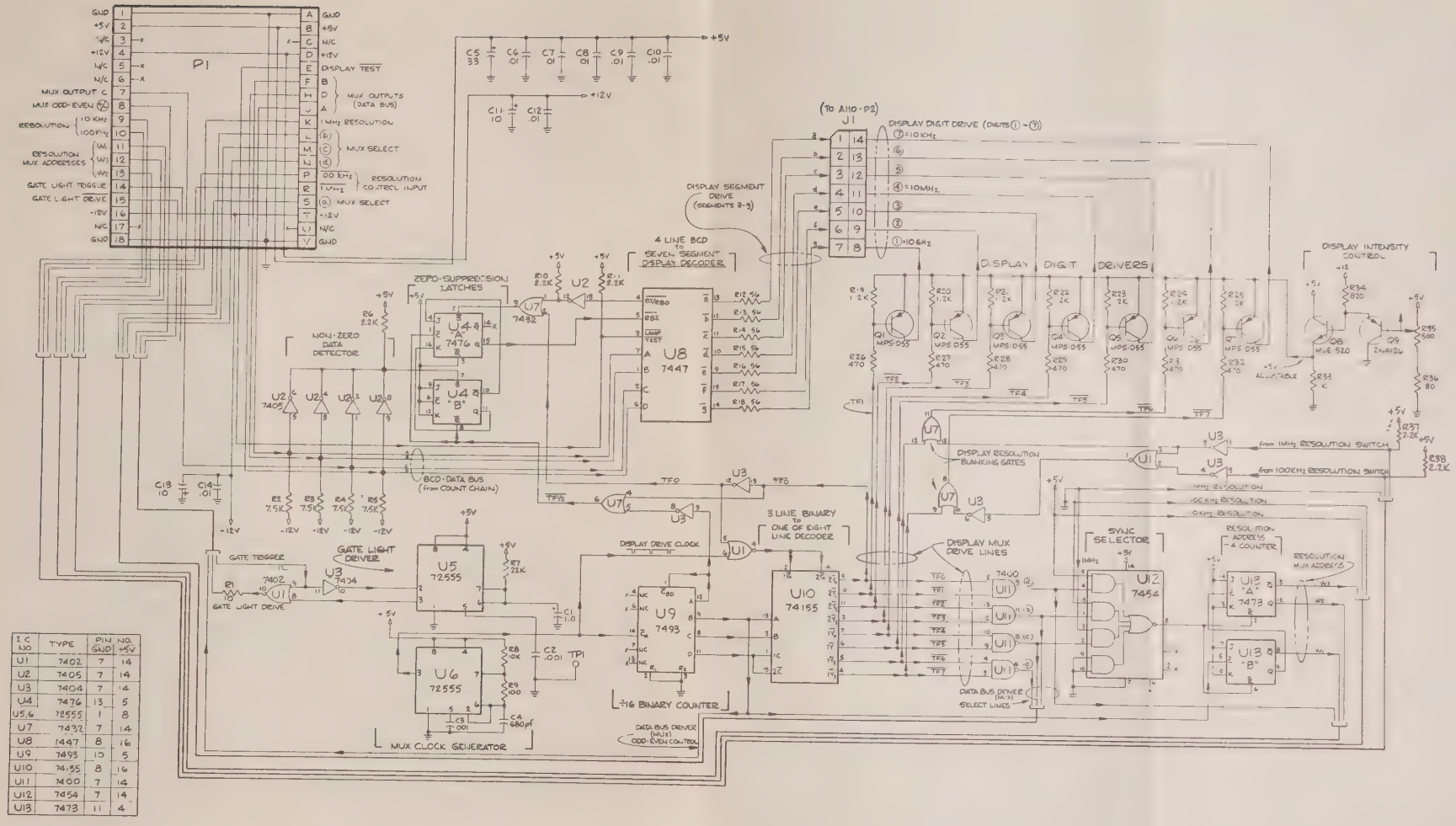
This address generator is available to provide for the possibility of changing the gate time of each measurement (the resolution) at the same time that the display blanking is changed by the RESOLUTION switches. (This requires factory modification of the counter.) In this case, the fastest DCU's of Count Chain A103 provide data to different digits of the display.

This may be controlled by providing offset addresses from A102. The fixed set of addresses is the four line data bus driver select signals. A variable address may be obtained from the binary outputs of the ÷4 counter (U13). These are normally reset through U12 when select line a is active in TF0 and TF1 times. This reset time may be varied if the 100 kHz and 1 MHz resolution lines are driven by the RESOLUTION switches (if the 10 kHz line is attached to U1 pin 1 rather than +5V, the 100 kHz to U3 pin 4, and the 1 MHz line to U3 pin 2 rather than ground). The reset time may then be TF01, TF2-3, or TF4-5, depending upon which resolution input to U12 is energized.

Gate Indicator Driver (U1, U3, U5)

The front panel GATE indicator is driven directly by NOR gate U1C in response to the gate trigger from A105. A second input to this gate is obtained from U5 which is also set by the gate trigger via inverter U3E. U5 is a one-shot whose period is set to about 30 ms. The drive pulse to the indicator in response to each gate trigger, is then of sufficient duration to be visible, even for very short gate times.

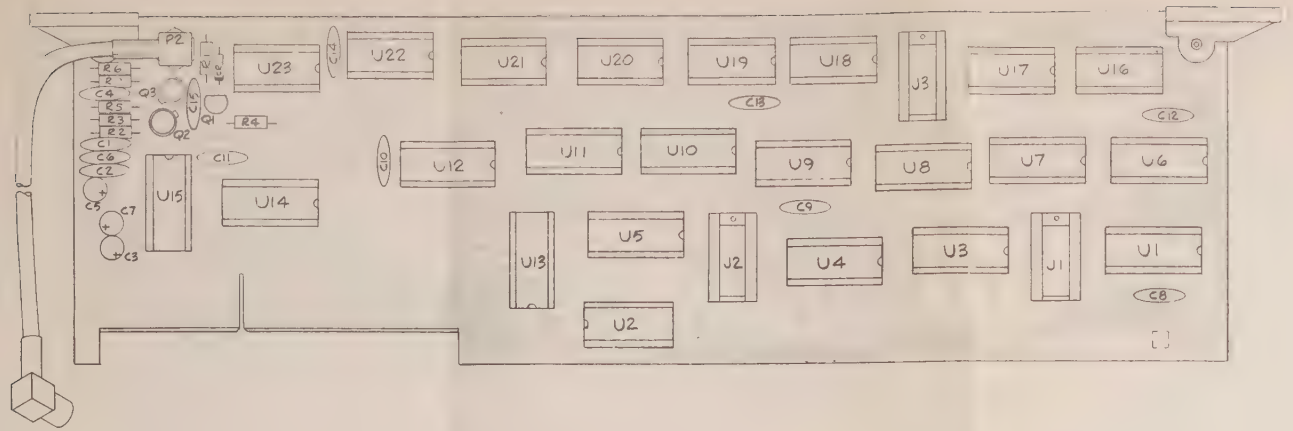
FIGURE 9-4A
COMPONENT LOCATOR
COUNT CHAIN CONTROL (A102)



IC NO	TYPE	PIN NO. GND	+5V
U1	7402	7	14
U2	7405	7	14
U3	7404	7	14
U4	7476	13	5
U5,6	72555	1	8
U7	7432	7	14
U8	1447	8	16
U9	7493	10	5
U10	74155	8	16
U11	7400	7	14
U12	7454	7	14
U13	7473	11	4

072B

FIGURE 9-4B
SCHEMATIC DIAGRAM
COUNT CHAIN CONTROL (A102)



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COUNT CHAIN (A103)

General

Count Chain board A103 accumulates the counts provided by the output of High Frequency board A106, and on command stores this BCD information in a separate storage unit. A multiplexer scans the information one digit at a time and presents the BCD digits serially on a four line output bus. (In Option P4, the same information is presented in parallel to a rear panel BCD output connector.) The last three DCU's (of the six total DCU's) may be preset before normal counting begins. The length of the counting chain may be changed by external controls which remove one or two DCU's from the chain. This allows correct front panel readings if the counting gate time is reduced by factors of 10 or 100.

The 451 Pulse Counter measures frequencies by dividing the input frequency in cascaded Decimal Counting Units (DCU's) for a precisely determined gate time. The number of accumulated counts divided by the gate time gives the frequency directly. The first DCU is on High Frequency board A106, and is followed by six more DCU's on this board (A103). Each DCU has a four-line BCD output to show its accumulated count. These BCD outputs are properly decoded to drive the front panel display which shows the value of the digits accumulated by each of these DCU's.

Counting Chain (U16-18, U21-23)

The counting chain includes six standard DCU's which are directly presettable integrated circuits. The first unit is a higher speed unit than the remaining five, since it operates at ten times higher speed than any following. The D output of each unit, occuring once for each ten input pulses, directly feeds the following DCU. Each DCU then divides the input by a factor of ten. The last three DCU's may be preset to any desired number by applying a load command before normal counting begins. This is used when the Converter (A2) is operating. This adds the Converter local oscillator frequency to the counting chain input to obtain the actual input frequency to the counter. Selector gate U20 is placed between U21-23, and the input to U18. This allows the output of either U21, U22, or U23, to be selected, eliminating U21 or U22 from the chain. U23, the fastest of these DCU's, is always left in the chain, so the maximum specified input frequency to the counter may always be counted correctly.

The input to the first DCU is obtained from transistor amplifier Q1-Q3. This translates the ECL level input to A103 from A106 to the proper TTL level to drive U23. It is a differential amplifier with an emitter follower output stage.

Storage Unit (U6-12)

Seven 4-bit IC latches are provided to store the information from the six DCU's of A103 and the first DCU of A106. The four BCD output lines of each DCU connect directly to the four input lines of each of the quad latches. A load command to all latches causes the DCU information to be stored and held until the next load command. All information from the counting chain to the rest of the counter is obtained from the outputs of these latches.

Data Output Multiplexer (U1, U3-5)

The counting chain data located in the storage unit latches is converted to a serial form required by the front panel display. Each IC multiplexer includes four separate channels, with one output and two inputs per channel. A single select input to each unit allows one or the other of the two inputs of each channel to be selected, with this input transferred to the output. The corresponding channel outputs of all four of the multiplexers are wired together to form a single output.

All outputs are tri-state, which means they may be gated into either an active or a passive state. The passive state is a high impedance state which does not respond to the input of that channel. The output may now be driven by any outside source connected to it. In the active state, the output responds directly to the input signals, producing the normal TTL driver output levels. Thus one active output may operate normally while wired to many passive outputs.

An input to each multiplexer IC is provided to select either active or passive output for that IC. The inputs are arranged so that only one of the four interconnected IC's has active outputs at any given time. The odd-even select inputs of all four IC's are wired together. This one select line, plus four gate lines to select the active or passive state for each multiplexer IC, allows any one of eight BCD inputs to be transferred to the multiplexer BCD output.

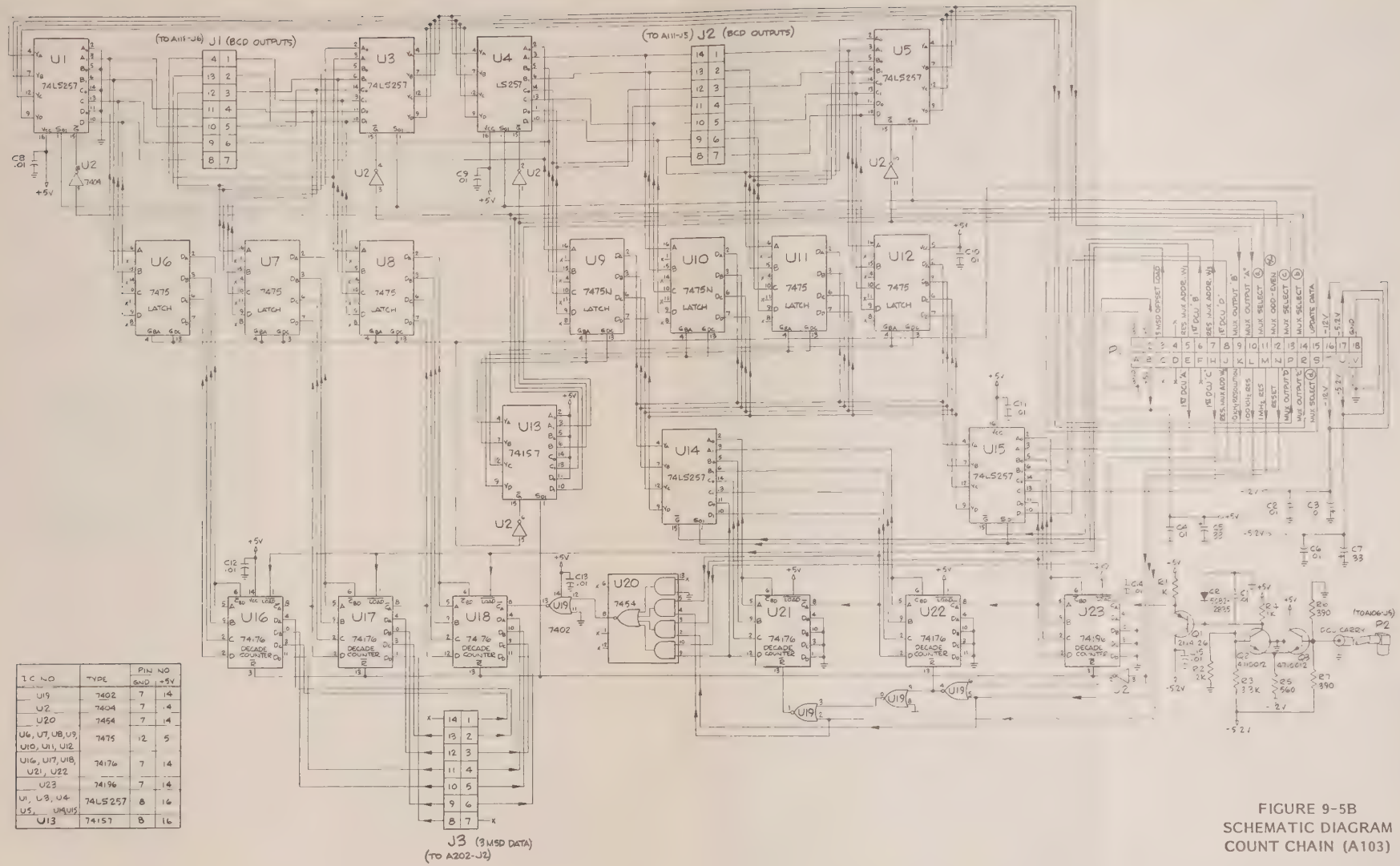
Resolution Multiplexer (U9-15)

Another multiplexer similar to the data multiplexer is used between the first four DCU's of the counting chain and their corresponding quad latches in the storage unit. This allows the position of a latch, into which data from a particular DCU is entered, to be shifted from the normal position. When DCU U21 is removed from the counting chain, data from U22 is shifted to latch U9, U23 shifts to U10, the first DCU of A106 shifts to U11, and U21 shifts to U12. U21 is held reset so U12 will receive a data zero. When U21 and U22 are removed, they are both held reset, and data from U23 goes to U9, from the first DCU on A106 to U10, From U21 to U11, and from U22 to U12.

The multiplexer portion of this unit operates in the same way as the Data Output Multiplexer. It includes two of the multiplexer IC's with tri-state outputs (U14 and U15). The inputs are connected to the BCD outputs of the first four DCU's. The A outputs and A inputs of the four latches (U9-12) are all wired together. The B outputs and latch inputs are also wired together, as are the C outputs to inputs, and the D outputs to inputs. The odd-even input select signal applied to both U14 and 15 selects inputs simultaneously, but separate gate inputs to select active or passive output states are provided. These are obtained from the Resolution Mux address generator on A102. The signals are synchronized with the MUX select a, b, c, and d signals, which operate the main Data Output Multiplexer. The phase of the two sets of signals may be changed however, if the Resolution Control signals are changed. The MUX select signals are fed to the latch load inputs through the tri-state multiplexer U13, which transmits the signals only while the Update command is in effect. In the normal 10 kHz resolution, the BCD data from the first DCU (on A106) is transferred through the U15 active outputs to the latch bus at the same time a load command is applied to latch U12. Data transfer is similar from the other three DCU's to their corresponding latches.

During reset, U13 applied a continuous load command to all four latches. The four DCU's driving the bus are also reset, so that the latches all receive an immediate load zero command when reset occurs.

FIGURE 9-5A
COMPONENT LOCATOR
COUNT CHAIN (A103)



IC NO	TYPE	PIN NO	
		GND	+5V
U19	7402	7	14
U2	7404	7	14
U20	7454	7	14
U6, U7, U8, U9, U10, U11, U12	7475	12	5
U16, U17, U18, U21, U22	74176	7	14
U23	74196	7	14
U1, U3, U4 U5, U14U15	74LS257	8	16
U13	74157	8	16

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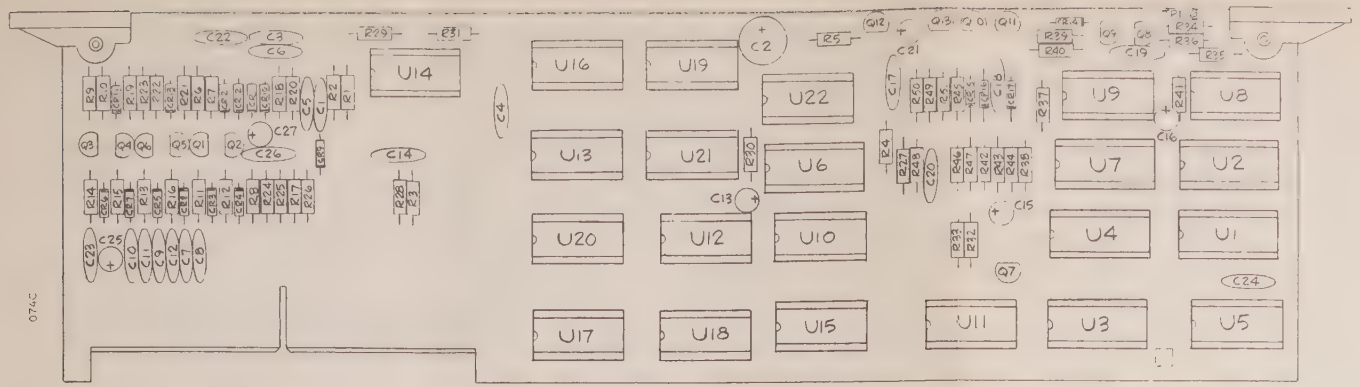
FIGURE 9-5B
SCHEMATIC DIAGRAM
COUNT CHAIN (A103)



CONTROL (A104)

General

The primary function of this unit is to control and step the counter through the sequence of operations required to measure the frequency of the input signal to the counter.

As with the central processing unit of a computer, generation of this sequence of commands to various portions of the counter is timed by an internal clock. The sequence may be modified by external control inputs, hence the outputs of most panel controls on the counter feed directly to this unit (TEST, BAND, RESET, etc.). Reset always returns the sequence immediately to a fixed starting point.

Control Sequence Generator (U1-5)

This unit produces control signals in sequence on one of sixteen output lines. U5 is a straight scale-of-sixteen binary counter which advances one state each time a clock pulse is applied to its input. The four outputs A, B, C, and D,are applied to two 3-8 line decoders (U3,U4) to produce an output on one of 16 lines corresponding to each of the sixteen possible states of binary counter U5. A reset signal to U5 returns the unit to the start of the sequence with the "0" output line active. A disable input to the decoders allows all outputs to be deactivated at any point in the sequence. This is used during the clock pulse or the reset input to U5 to prevent false outputs on any decoder lines from occurring during times when the counter outputs are in transistion between states.

Flip-flop U2A is used to indicate whether the sequence is in one of the states "0" through "9" or in one of the states "10" through "15". After state "9", the frequency measurement is already complete but not yet displayed. The reaction to external interrupts is then different in these two cases.

Flip-flops U1A and U1B are used to produce a much longer than normal step in the control sequence. This allows extra time to read data from the DCU's of the Count Chain in A103 through a multiplexer into latches which hold this data. Output state "11"" sets flip-flop U1A which immediately gates off all the decoder outputs via gates U10B, U9B, U11A, and U11B. The sequence generator then operates at full speed in states "12" through a second "12". Flip-flop U1B is set by the D output of U5 while going into state "8", which reactivates the decoder outputs. The output during state "12" is able this time to reset both U1A and U1B, and return the sequence generator to normal operation. The DATA UPDATE output during this long step of the sequence is obtained from U1A rather than from the decoder outputs.

Decoder outputs "13" and "14" are combined in U16 to produce a Print Command pulse twice the duration of the normal sequence outputs.

The control sequence may be frozen in any state by interrupting the clock input to binary counter U5.

Control Sequence

There are 16 output lines from the decoders which are energized in sequence each time the counter repeats a measurement cycle. The operations which correspond to commands on each of these lines 0-15 are listed in Table 9-6A.

Any of the normal times listed the Table may be extended by interrupting the sequence clock. The times listed as variable in the Table are controlled by internally generated interrupt signals. With Programming Option P4, such an interrupt may be applied from outside the counter. This might occur with a printer, which must freeze the data in the counter until printing is complete. Other interrupts may be generated internally, depending upon the state of the input signal to the counter.

Control Sequence Reset or Interrupt Conditions

The Sequence Generator is reset to its "0" state in a variety of conditions where a measurement has started but cannot be successfully completed. The reset then prevents erroneous data from being displayed or sent out to other remote equipment. The actions that cause these resets include: externally controlled changes of the mode in which the counter operates (band change, Test, etc.),or large changes in the input signal itself before a successful measurement can be completed. The sequence can also be interrupted or reset by direct external commands.

Events which cause both reset of the sequence to "0" and Converter recycle (plus immediate zero display), are as follows:

a. Counter power turn-on.
b. Switch to Band B.
c. End Test in Band B.
d. Reset commands externally or manually applied.

Other events which cause the sequence to be reset to "0":

a. Change of RESOLUTION controls.
b. Switch to Band A.
c. Start Test.
d. End Test in Band A.
e. Start-cycle command from external source.
f. Converter lock or unlock in Band B during sequence "0" - "9".
g. PRF limit signal changes state (input signal appears or drops out) during sequence "0" - "9".

A number of conditions also cause the sequence to be inhibited:

a. A direct Sequence Inhibit command from an external source.
b. Operation of the Display Time Generator. This produces a variable time inhibit controlled by the SAMPLE RATE control or a permanent inhibit with the control at HOLD. A reset (external or manual) command over-rides this signal and causes a single sequence before the inhibit is re-established.
c. Operation of the Gate Generator (A105). During Sequence "8" if the counter is in Test or locked to an input signal, the Gate Generator inhibits the sequence until the prescribed gate time is accumulated. Input signal dropout removes this inhibit unless the unit is in the Test mode.
d. PFR limit signal appears (input signal level above threshold) in Band B, but Converter LOCK absent. A delay is produced before sequence continues (or resets) to see of Lock will soon be achieved.
e. LOCK lost in Band B. Time is allowed for relock to a measurable input signal before a reading of zero is produced. This prevents zero readings when lock is broken, even though a measurable input is present continuously.

Reset Pulse Trigger Generators

A large proportion of A104 consists of circuits which reset the sequence generator or other portions of the counter. The triggers which operate the reset generators are formed from the various inputs in the same way. The input signals are step functions which are differentiated in RC networks (C16, R37, for example), and coupled through diodes to a common two transistor output stage (Q10, Q11, for example). The TTL compatible output trigger then drives the IC reset generator or gate.

Six inputs to C7-C12 are combined in diodes CR3 - CR8 and output stage Q3, Q4 to reset the sequence generator through gate U11D. Four additional inputs to C3-C6 are combined in CR10-CR13 and output stage Q5, Q6 to drive OR gate U22A. During sequence states "0" - "9", this gate drives the first network through CR9 and resets the sequence generator if any input to C3-C6 occurs during states "0"-"9".

Three inputs to C17 - C19 drive a similar network through CR15 - CR17, and Q9, Q9. These trigger the reset generator one-shot U7A, which produces a uniform pulse about 5 μs in duration. This pulse resets the sequence generator, the display generator, the lock delay generator, and externally the Count Chain and Converter. The Count Chain immediately generates and displays a zero.

The inputs to C18 and C19 are obtained from Schmitt triggers in U9. Inputs to U9 are slow rise signals which are changed to single fast steps by the threshold circuits of U9.

FIGURE 9-6A
COMPONENT LOCATOR
CONTROL (A104)

SEQUENCE	FUNCTION	DURATION
0	Reset - Resets "0" - "9" Detector.	10 μs
1	Reset - Counting Chain reset to zero.	10 μs
2	Offset Load - Last three DCU's of Count Chain set to any desired number.	10 μs
3	Blank	10 μs
4	Blank	10 μs
5	Blank	10 μs
6	Reset Time Base Generator - Resets Time Base Flip-flop and accumulator on A105.	10 μs
7	Blank	10 μs
8	Signal Gate Enable - Allows Gate Generator (A105) to open the signal gate for the prescribed gate time in response to indication of a measurable input signal to the counter. This is the period when the measurement of input signal frequency actually occurs.	Variable
9	Blank	10 μs
10	Measurement complete - Sets "0" - "9" Detector to show that measurement portion of cycle is complete.	10 μs
11	Update Data - Latches associated with each DCU of the counting chain are latched to new DCU data.	170 μs
12	End Update Data - Resets update data flip-flops.	10 μs
13 14	Print - Sends out signal indicating that new measurement data is available.	20 μs
15	Display - Starts variable time delay, controlled by SAMPLE RATE control, which separates successive measurement cycles.	Variable

TABLE 9-6A. CONTROL SEQUENCE

Display Time Generator

After each measurement is complete, this unit inhibits the Sequence Generator for a time interval determined by the front panel SAMPLE RATE control. In the HOLD position, the inhibit is permanent until a manual or external reset command is applied, or the power is turned off.

The generator includes a variable period one-shot U7B and DCU U8. The one-shot is connected to produce a free running multivibrator during the delay time. Its output drives the DCU, which extends the period of the one-shot by a factor of ten. The only output of the display generator is a sequence inhibit signal. The DCU outputs are combined to inhibit the sequence, in all but the DCU "9" state. This signal is further combined with the sequence "15" and Fast Cycle controls so that inhibit can occur only in sequence "15" with Fast Cycle not applied and with the display generator DCU not in the "9" state. The Hold input keeps the DCU at "0" state, which applies a permanent sequence inhibit in sequence state "15" as long as Fast Cycle is not applied (or the unit reset).

To start the display time, the DCU is set from the previous "9" state to "0" during Sequence "14". At Sequence "15", the display time one-shot is triggered and commences to free run at a rate determined by the SAMPLE RATE control setting (approximately .3 - 30 pulses per second). Unless held reset by a Hold command, the DCU is stepped at this same rate until it reaches state "9". The sequence inhibit is then removed and the sequence continues normally, thus ending the display time.

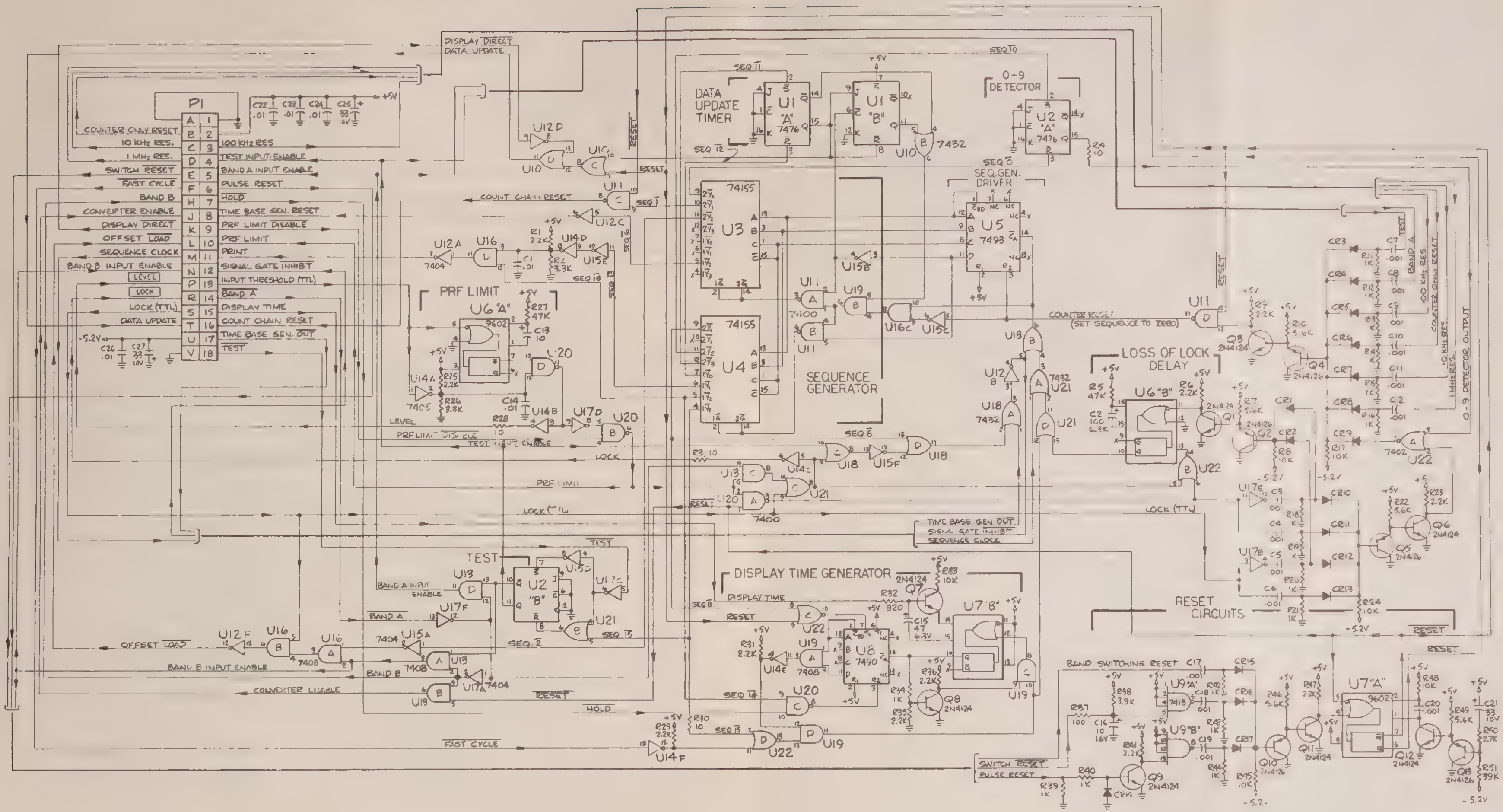
Test Mode

The circuits involved in test mode generation are primarily Test Flip-flop U2B. The input command is inverted and drives the flip-flop into the set state. It is held in this state until the input command is removed. Sequence Generator "15" output then resets the flip-flop at the end of the measurement cycle. Outputs of the flip-flop reset the sequence generator at start and finish of TEST, supply TEST commands to the Gate Generator (A105) and the High Frequency (A106) boards, remove the Offset Load command in Band B, and remove the Band A and B control signals to A106. The outputs provided cause the counter to measure an internal 200 MHz test signal as long as the Test Flip-Flop is held set.

PRF Limit

The PRF Limit circuits receive the input threshold signal from Gate Generator A105. This signal is present whenever the input signal to the counter is above the preset threshold level, and absent when it is below this level. The PRF circuit then produces a continuous output unless gaps in the input exceed about 100 ms, indicating a dropout of the input signal. The PRF Limit Disable input, when active, causes the PRF circuit to produce a permanent high output, despite the disappearance of the input signal.

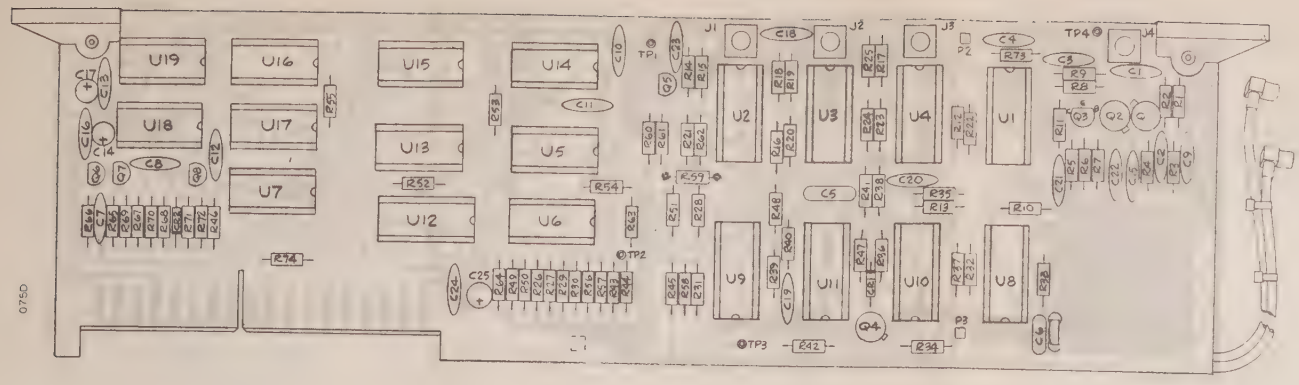
The PRF circuit includes a one-shot (U6A), triggered by the step which occurs when the input threshold signal disappears. The threshold signal also produces a fast-fall, slow-rising output from inverter U4A with C14, R25, and R26 load. This signal and the one-shot Q output are combined in NAND gate U20D to produce a signal that rises rapidly with appearance of the threshold signal. It does not fall however, unless the threshold signal stays low for more than 100 ms (the time constant of the one-shot.)


P1
COUNTER ONLY RESET
10 KHz RES.
1 MHz RES.
SWITCH RESET
FAST CYCLE
BAND B
CONVERTER ENABLE
DISPLAY DIRECT
OFFSET LOAD
SEQUENCE CLOCK
BAND B INPUT ENABLE
LEVEL
LOCK
LOCK (TTL)
DATA UPDATE
100 KHz RES
TEST INPUT ENABLE
BAND A INPUT ENABLE
PULSE RESET
HOLD
TIME BASE GEN. RESET
PRF LIMIT DISABLE
PRF LIMIT
PRINT
SIGNAL GATE INHIBIT
INPUT THRESHOLD (TTL)
BAND A
DISPLAY TIME
COUNT CHAIN RESET
TIME BASE GEN. OUT
TEST
DATA UPDATE TIMER
0-9 DETECTOR
SEQ.GEN. DRIVER
SEQUENCE GENERATOR
PRF LIMIT
LOSS OF LOCK DELAY
COUNTER RESET (SET SEQUENCE TO ZERO)
DISPLAY TIME GENERATOR
RESET CIRCUITS
BAND SWITCHING RESET
0-9 DETECTOR OUTPUT

BOX ▭ DENOTES FRONT PANEL INDICATOR.
ALL DIODES ARE 1N4154.

074A

FIGURE 9-6B
SCHEMATIC DIAGRAM
CONTROL (A104)



GATE GENERATOR (A105)

GENERAL

The primary function of this unit is to produce the Gate signal which controls the time intervals over which the input to the counter is accumulated. It also produces the 100 kHz Control Sequence Clock and a 200 MHz Test signal. These outputs are all based on 200 MHz and 10 MHz references supplied from other portions of the counter.

Gate and Enable Flip-Flops (U8A/B)

The flip-flops are a dual ECL type, both clocked by the same 200 MHz reference signal. The Gate Flip-flop controls the main counter Signal Gate directly, while the Enable Flip-flop determines which cycle of the 200 MHz clock will trigger the Gate Flip-flop.

The enable signal to the Enable Flip-flop is derived from the counter input threshold circuit and is present only at times when an input signal of adequate amplitude is present. This signal is combined with a signal from the counter Control board A104, which indicates that the counter is in the correct part of its cycle to actually measure the input signal frequency. The rise time of the enable signal is faster than the clock period, so that the Enable Flip-flop has always settled definitely into one of its two stable states when any individual clock pulse arrives.

The output of the Enable Flip-flop is applied to the enable input of the Gate Flip-flop which is triggered to the corresponding state by the next 200 MHz clock pulse. Transitions of the Gate Flip-flop occur only at a defined trigger point on the clock pulse, which is timed very accurately (<< 1 nsec from periodic 200 MHz). The output of the Enable Flip-flop is also combined with the output of the Time Base Flip-flop (U10B). This allows only a specified number of clock pulses to occur during the gate time of each measurement cycle of the counter. The accumulated gate times are: 1, 10, or 100 μs (4, 40, or 400 μs in Band A). The Gate control signal is applied via a 50 ohm cable to the signal gate on High Frequency board A106.

Time Base Flip-Flop (U10B)

This is another fast ECL flip-flop. It is clocked by a 200 MHz signal slightly delayed from that driving the Enable and Gate Flip-flops. The delay is to allow the Gate Flip-flop (triggered by the normal clock) to control the delayed clock during the same clock period in which the Gate Flip-flop changes state. The clock delay and propagation delay through the flip-flop are approximately equal. The Time Base Flip-flop is reset at the beginning of each measurement cycle, removing the disable signal applied by it to the Gate Flip-flop.

During the gate enable portion of the counter control sequence, the Gate Flip-flop is controlled by the input threshold circuits via the Enable Flip-flop and the 200 MHz clock. Each time the Gate Flip-flop opens the Signal Gate, the 200 MHz delayed clock is also applied to the Time Base Accumulator and to the Time Base Flip-flop clock input. The clock pulse which opens the Signal Gate is ignored. All pulses which occur during a Signal Gate open period are recognized, including the one which closes the Gate. Coincidence circuits in the Time Base Accumulator produce signals when N-4 and N-3 clock pulses have been applied to the Accumulator. N is the number of clock periods required to produce the desired accumulated gate time. The N-4 signal is applied to the clock enable input, and the N-3 signal to the enable input of the Time Base Flip-flop. The N-2 clock pulse then actually triggers the Time Base Flip-flop to its set state. The delay already present in the delayed clock driving the accumulator is extended by a delay network following the Time Base Flip-flop. The disable signal from the Time Base Flip-flop to the Gate Flip-flop input is then delayed until after the N-1 normal clock pulse. The N clock pulse resets the Gate Flip-flop and ends gate time for that measurement cycle.

Time Base Accumulator (U10A,U11,U14-U16)

The Time Base Accumulator includes four decimal counting units (U11,U14-U16) preceded by a binary divider. The count capacity of this group is 20,000 clock pulses, each of 5 ns period, or 100 μs total. The last two DCU's may be removed from the string to give 10 μs or 1μs gate times. In addition to the string of DCU's, a ÷4 unit is included between the first and second DCU's which may be switched into or out of the chain. The ÷4 is included when operating in Band A to increase the gate time by a factor of four. The input to High Frequency board A106 is divided by four before reaching the Signal Gate, so the gate time must be extended to make the counter read the input frequency directly.

A coincidence detector consisting of U4B, U7A/B/C/E, -U13C, U17A/B,Q8, CR1, and the D output of U11, produces an output when all DCU's of the string are in state "9" and the ÷4 unit is in state "3". The first DCU of the string is preset to 9 originally (driving C_{BD} input with the A, rather than the inverted A output, is equivalent to preset 9), giving coincidence after N-2, rather than N-1 clock pulses to the first DCU. Since the accumulator clock input is divided by two in binary U10A before the first DCU, coincidence output occurs on the N-4 input pulse.

Since coincidence occurs when all DCU's are at 9 and the ÷ 4 at 3, any one of them is effectively removed from the string if held at these counts. U15 and U16 have external set 9 inputs to produce the shorter 10 and 1μs gate times in this manner. U16 alone, or U15 and U16 together, are held in this state. This ÷4 unit may also be held at 3 by an external control signal (Band B or Test), but additional gating must be provided to pass the input signal around the stage, since the following DCU's still have to operate. This is accomplished in U5C/D, U6D, and U13D, which transmit either the input or the output of U12 to the input of U14.

The ÷2 and the first DCU of the Accumulator are fast ECL circuits, able to divide the 200 MHz clock to 10 MHz; the remaining circuits are TTL.

200 MHz Reference Shaper (Q1-Q3)

This circuit converts the input sine wave into an ECL signal. Q1 and Q2 act as a current switch to drive the emitter of Q3. R5 and R6 set the output voltage level.

Band Select Circuits (U2B/C,U3B/C,U4A/C)

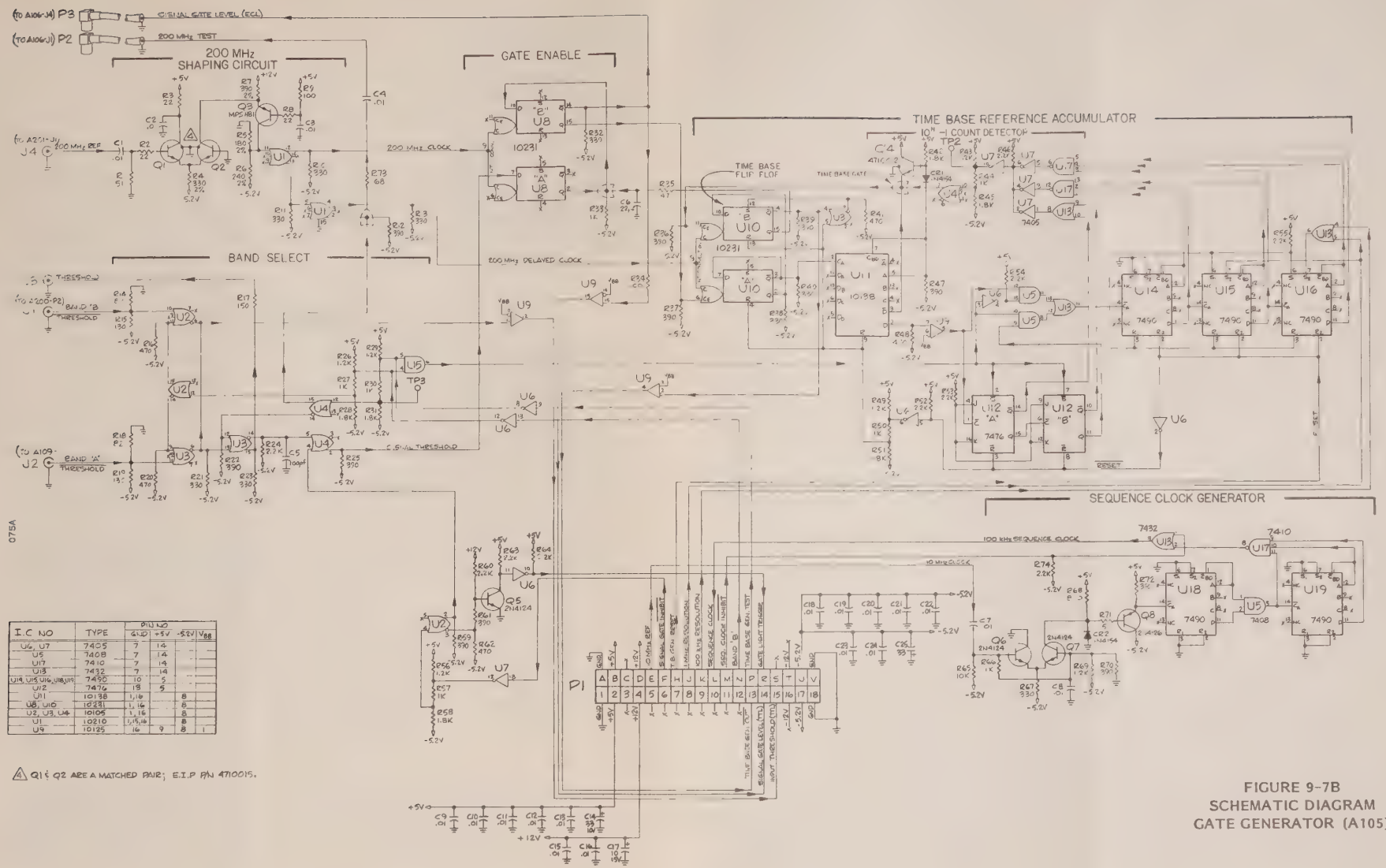
These circuits select one of the Band Threshold signals from either the Converter (Band B) or the Prescaler (Band A) and processes this to control the Enable and Gate Flip-flops. U2C is simply a buffer/inverter which is driven by a level derived from the front panel band switch. The buffer output drives one input of U2B, and the inverter output drives one input of U3B, so that one of the pair U2B/U3B is always enabled and one disabled. The inverting outputs of U2B and U3B are "ORed" together to drive one U3C input. The direct output of U3B is now a replica of the envelope of the signal to the selected input to the counter, being high if the signal is above threshold level, and low if the signal is less than threshold. The second input to U3C is high in the Test mode, so the Gate Flip-flop operates as if the 200 MHz test signal is always above threshold level.

The output of U3C to the Enable Flip-flop goes low whenever the input signal to the counter is above threshold. A capacitor to ground slows the fall of this transition without great effect on the risetime. This signal is squared up again in U4A to produce an Enable signal which is delayed from the rise of the input signal to threshold, but disappears without delay as the input drops below threshold. This effectively shortens the enable signal to the Gate Flip-flop so the GATE signal may be properly timed to coincide with the signal to be counted on the High Frequency board (A106). A second input to U4A allows the Gate to be inhibited by the control sequence generator.

Control Sequence Clock Generator (Q6-8, U10,11,13,19)

This circuit divides the input 10 MHz reference by 100 to form the 100 kHz Sequence Clock. Q6 and Q7 are a differential amplifier with Q8 emitter follower output to drive DCU U18. The input accepts a wide variety of input levels and waveshapes while producing a square wave of the proper level to drive U18. U5A and U17C gate the outputs of U18 and U19 to form short (100 ns) pulses. U13A allows the Clock to be gated by an external control level.

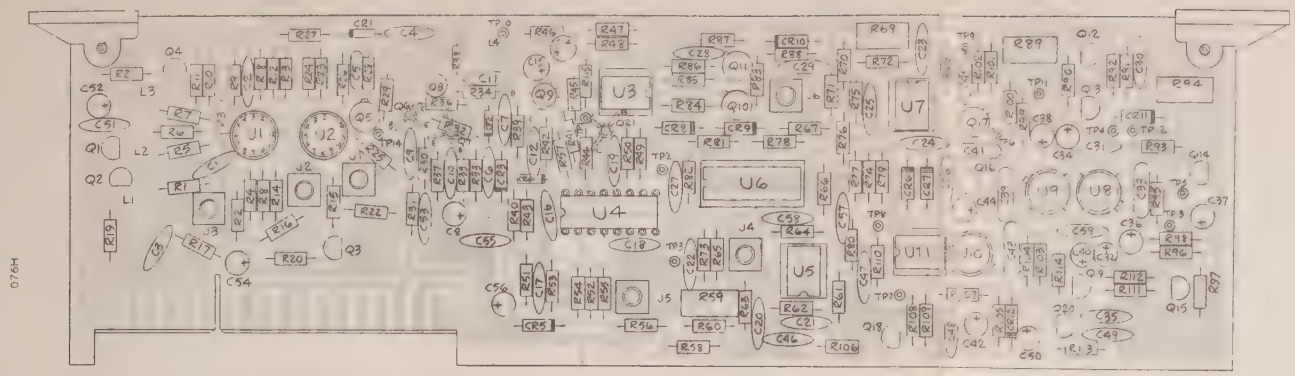
FIGURE 9-7A
COMPONENT LOCATOR
GATE GENERATOR (A105)



I.C NO	TYPE	PIN NO			
		GND	+5V	-5.2V	V_{BB}
U6, U7	7405	7	14	-	-
U5	7408	7	14	-	-
U17	7410	7	14	-	-
U13	7432	7	14	-	-
U14, U15, U16, U18, U19	7490	10	5	-	-
U12	7476	13	5	-	-
U11	10138	1,16	-	8	-
U8, U10	10231	1,16	-	8	-
U2, U3, U4	10105	1,16	-	8	-
U1	10210	1,15,16	-	8	-
U9	10125	16	9	8	1

⚠ Q1 & Q2 ARE A MATCHED PAIR; E.I.P P/N 4710015.

FIGURE 9-7B
SCHEMATIC DIAGRAM
GATE GENERATOR (A105)



HIGH FREQUENCY (A106)

The High Frequency board provides the initial signal processing and first decade of counting for the Direct Counter. It selects and processes one of three input signals: the Converter IF output, the Prescaler divide-by-four output, and the 200 MHz Test signal. BCD information and the divide-by-ten output from the first decade counting unit are sent from this board to the Count Chain board (A103) for further counting and display.

One of the three input signals is selected by enabling one of three differential amplifiers: U1B, U2A, or U2B. U1A provides additional gain for the Converter IF signal when

fier is achieved by activating transistor Q2, Q3 or Q4, by TTL Band Select commands entering on J1.

The output of the input selector differentially drives the squaring circuit. Q5 is a current mirror, which is used as an overdriven voltage-to-current converter. The collector current of Q5 drives the pulse forming network which begins with a wide-band, high-speed differential amplifier (Q6/Q7). The output of this differential amplifier drives Q8, which is used as a current switch. The resulting current square wave from U8 drives inductor L3, producing a series of pulses — a positive pulse when Q8 turns on, and a negative pulse when Q8 turns off.

The pulse inverter is essentially a high-speed zero bias amplifier. Q9 performs this function by being biased at cut-off by diode CR4. In this mode, the amplifier not only inverts the positive pulses, but removes the unwanted negative pulses. The output of the pulse inverter drives the input of decade divider U4. The bias point for U4's input is established by a tracking bias supply (U3/Q21). The output of U3 is equal to the voltage on U4 pin 1, plus a fixed DC offset selected by resistor divider R46/R47. The divide-by-ten output of the decade divider is a 60/40 duty cycle ECL level signal called "DCU CARRY". The load resistor for this signal is located on the Count Chain board (A103) to provide a termination for the connecting co-ax cable.

The BCD output information is available on P1 pins 11-14. During a count cycle at high frequencies, this information is slew rate limited, therefore the actual output levels cannot be seen until the circuit comes to rest. After the circuit is finished counting, TTL level signals are present on these outputs. The decade divider is reset after the counting cycle is complete by a TTL reset signal on pin 3. This signal comes into the board via P1 pin 10.

The gate signal, an inverted ECL level logic signal, enters the board at J4, and passes through the variable gate delay circuitry. The first stage is an input buffer whose threshold signal (U6 pin 5) is derived from an op amp temperature compensated bias supply (U5). U5's function is similar to U3 with the output tracking the reference voltage (U6 pin 11), plus some fixed offset supplied by voltage divider R58-R60.

The gate signal is coupled between the first and second stages, and the second and third stages of U6, by RC delay networks R74/CR6 and R79/CR7. The delay time of these networks is controlled by the back bias on voltage variable capacitors CR6 and CR7. This delay time is either set for minimum delay time (rear panel GATE MOD switch OFF), or a random delay selected by the output of the sampled noise voltage generator.

The sampled noise voltage generator begins with a noise diode (CR11) driven by a temperature compensated constant current generator (Q12/Q13). The curent is adjusted by R89 until maximum noise appears at TP4. U8 is the gain stage of an AGC amplifier. The output noise of U8 is detected by Q15, with the resultant DC voltage applied to the gate of a voltage variable resistor Q14. R94 is used to offset the combined voltage errors of U8-U10.

U9 is a voltage follower used to generate a very low impedance drive signal for the sample and hold circuit (Q16 and C41) that follows. The drive signal for Q16 begins at differential amplifier Q10/Q11. At the end of each gate signal Q11 turns on, generating a negative-going signal on R87. This signal is differentiated through C29 and R88, with the resulting negative spike AC-coupled onto the base of Q17 to turn it off for approximately 40 ns. When Q17 turns off, the gate of Q17 goes positive and Q16 turns on, charging C41 up to the output voltage of U9. Q16 then remains off (holding) until the next gate time is over and a new sample is taken. U10 is a high impedance buffer for the voltage across C41. The voltage out of U10 (at TP7) is level shifted by U11 and applied to the RC delay diodes (CR6/CR7). When the modulation enable is turned off, Q18 applies -12 volts to the input of U11. The output of U11 goes to its most negative voltage (about -11 volts) which gives minimum delay. Q19 is a clamping diode to keep the diode bias line from going positive.

FIGURE 9-8A
COMPONENT LOCATOR
HIGH FREQUENCY/-
GATE MODULATOR (A106)

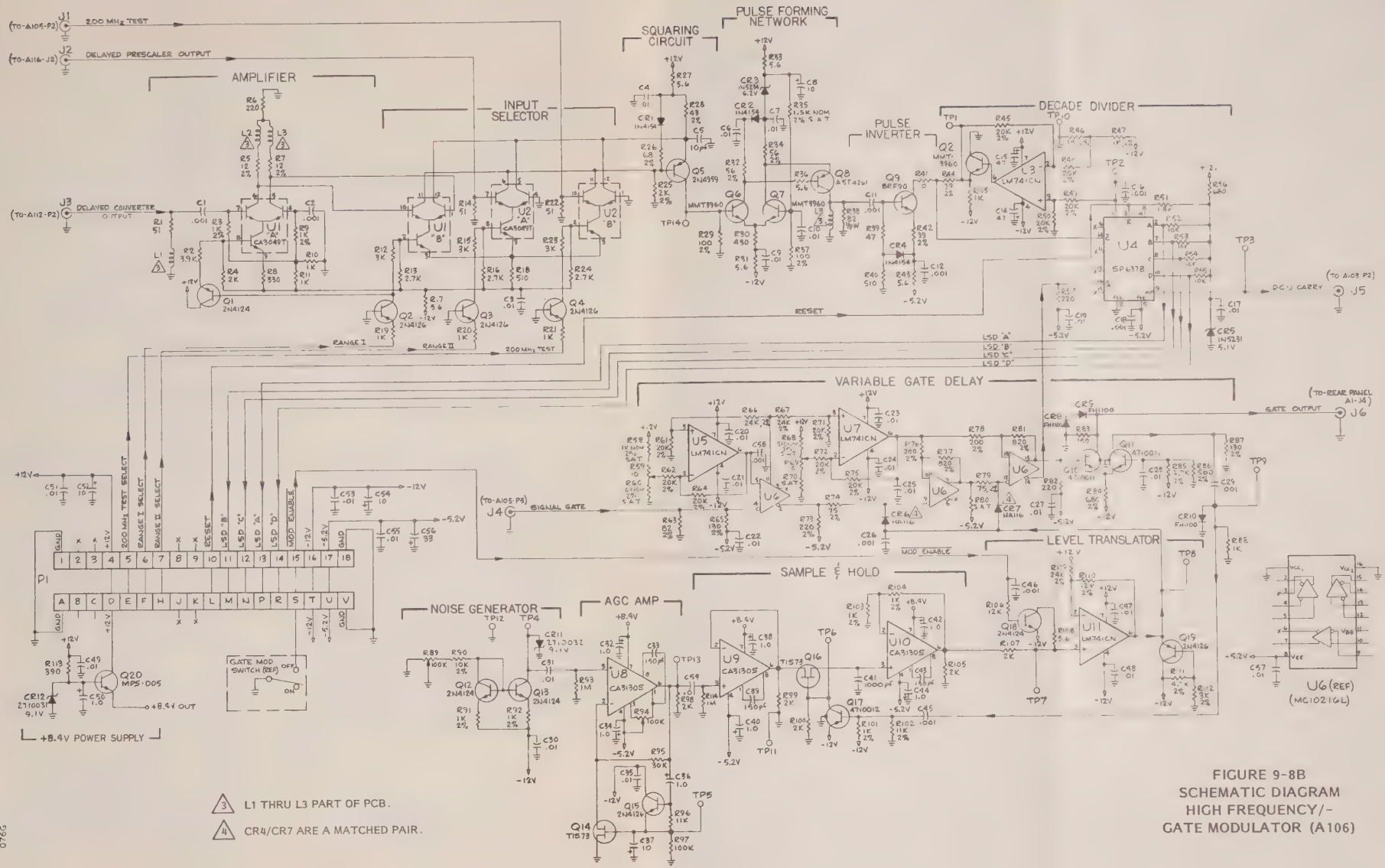
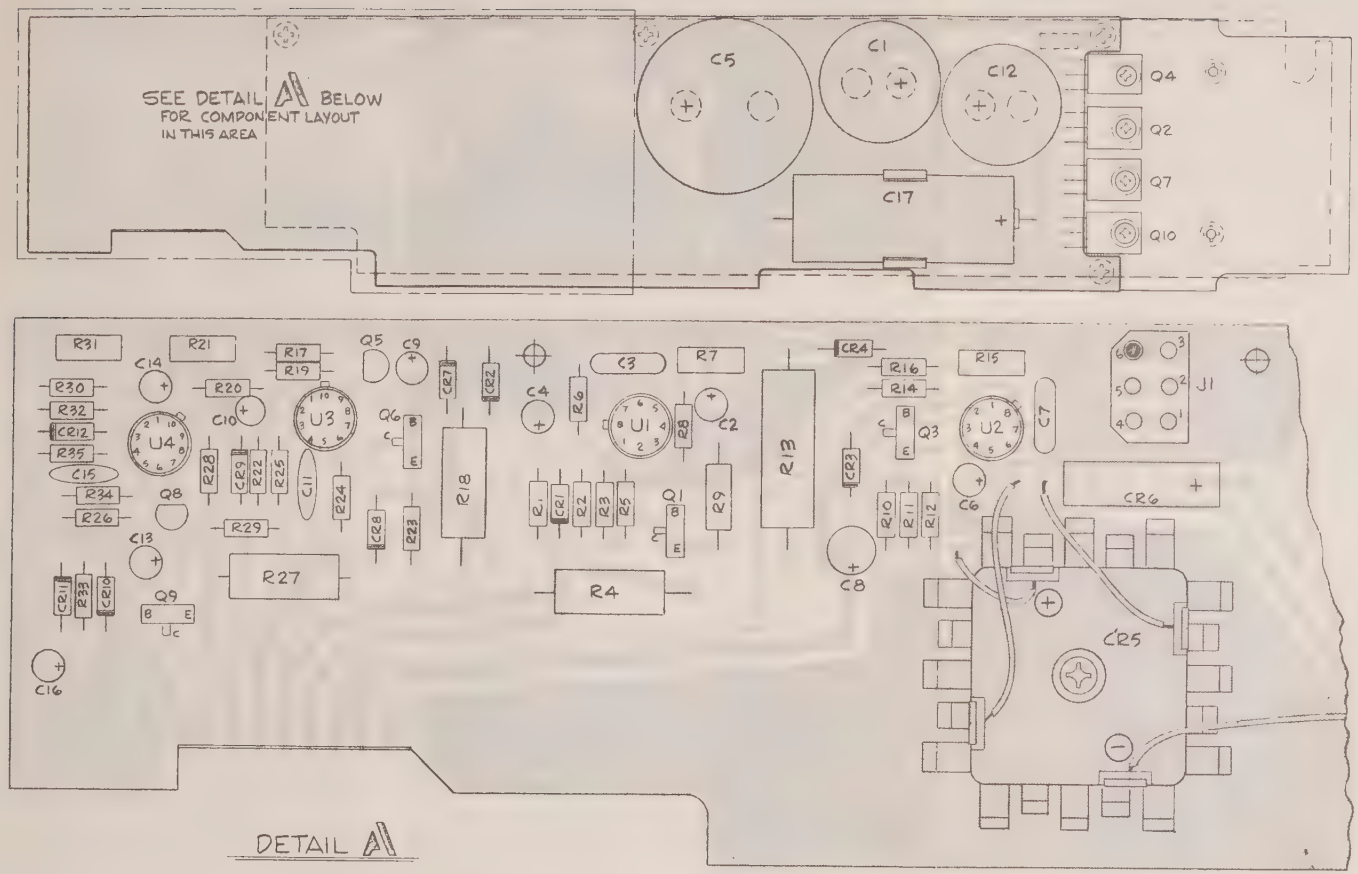


FIGURE 9-8B
SCHEMATIC DIAGRAM
HIGH FREQUENCY/-
GATE MODULATOR (A106)

3 L1 THRU L3 PART OF PCB.

4 CR4/CR7 ARE A MATCHED PAIR.

0766



POWER SUPPLY (A1/A107)

The Power Supply furnishes all basic operating voltages required by the counter. The supply consists of two assembly groups:

(1) PC board A107 containing the rectifiers, filter capacitors, and regulator circuitry.

(2) Chassis mounted components (A1-) consisting of the power transformer (A1T1), primary wiring, POWER INPUT module (containing the fuse, voltage changing PCB, and power input connector), and the front panel POWER switch.

Circuit Description

The basic voltages required by the counter are: unregulated +18 Vdc, regulated +12 Vdc, -12 Vdc, +5 Vdc, and -5.2 Vdc.

All the regulated voltages are produced by full wave rectifier and series regulator circuits. The +18 V unregulated voltage is also the input voltage for the +12 V regulator.

Each of the four regulator circuits contains an integrated circuit voltage regulator with current foldback capability, protective diodes, and provision for adjustment of the required output voltage.

The type of IC used in both the +12 V and +5 V regulators is an LM 305. This IC contains an internal temperature compensated voltage reference, as well as the necessary circuits to provide gain and current foldback limiting. The foldback current limit control resistors in the +5 V supply (for example), are R11, R12, and R13.

The negative supplies utilize an LM 304 as the basic IC regulator. This IC also contains an internal temperature compensated reference. To implement this reference an external pre-regulator is required. In the -12 V circuit (for example), the pre-regulator includes R22, R25, and CR9. Current foldback limiting uses internal IC circuitry in addition to R17, R18, R19 and Q5.

FIGURE 9-9A
COMPONENT LOCATOR
POWER SUPPLY (A107)

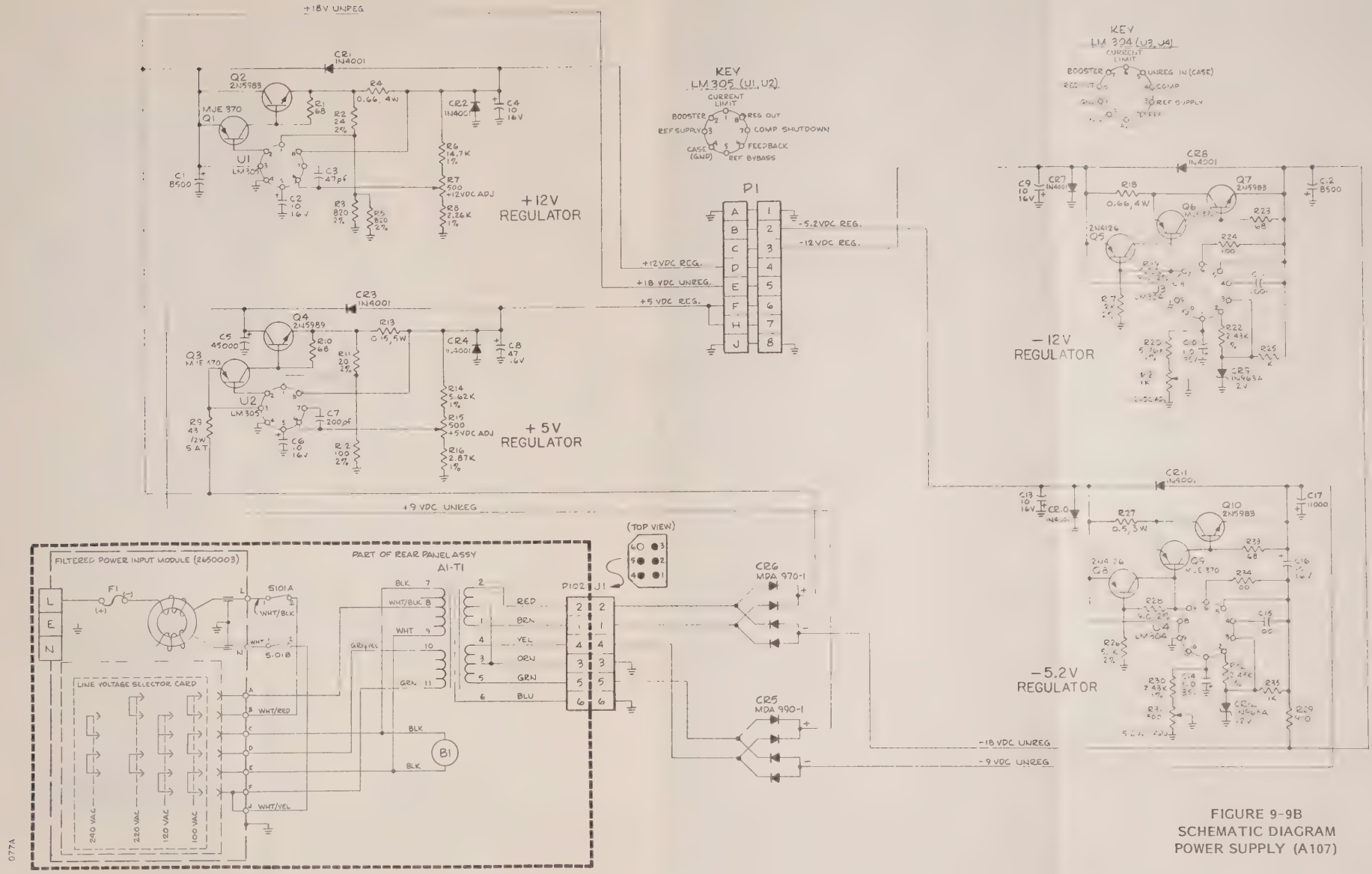


FIGURE 9-9B
SCHEMATIC DIAGRAM
POWER SUPPLY (A107)

REFERENCE OSCILLATOR BUFFER (A108)

GENERAL

A room temperature, crystal controlled oscillator (RTO) is used as the basic reference against which all input signals are compared. An additional temperature-compensated crystal oscillator (TCXO) is available as Option P1, which allows the user to select a higher level of precision compatible with measurement requirements.

Circuit Description

The signal from the oscillator is either a square wave from the RTO, or a sine wave from the optional TCXO. This waveform is converted to a positive-going square wave at J1 by a linear amplifier (Q1), current switch (Q2,Q3), and an output current driver (Q4).

The outputs appearing at P1 pins 6 and 14,are processed by a linear, low gain amplifier pair (Q5 and Q6), and two identical line driver circuits Q7-Q10, and Q11-Q14). Low gain, common emitter input stages (Q7,Q11), are followed by emitter followers (Q8, Q12), which drive push-pull emitter follower output pairs (Q9,Q10, and Q13,Q14).

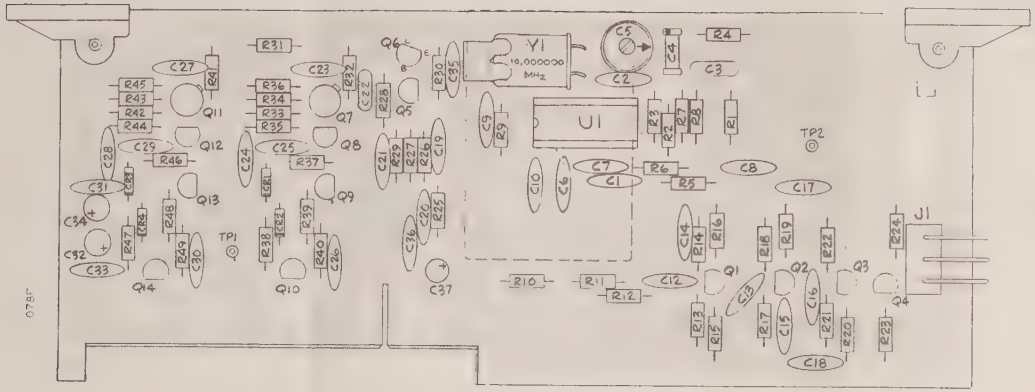
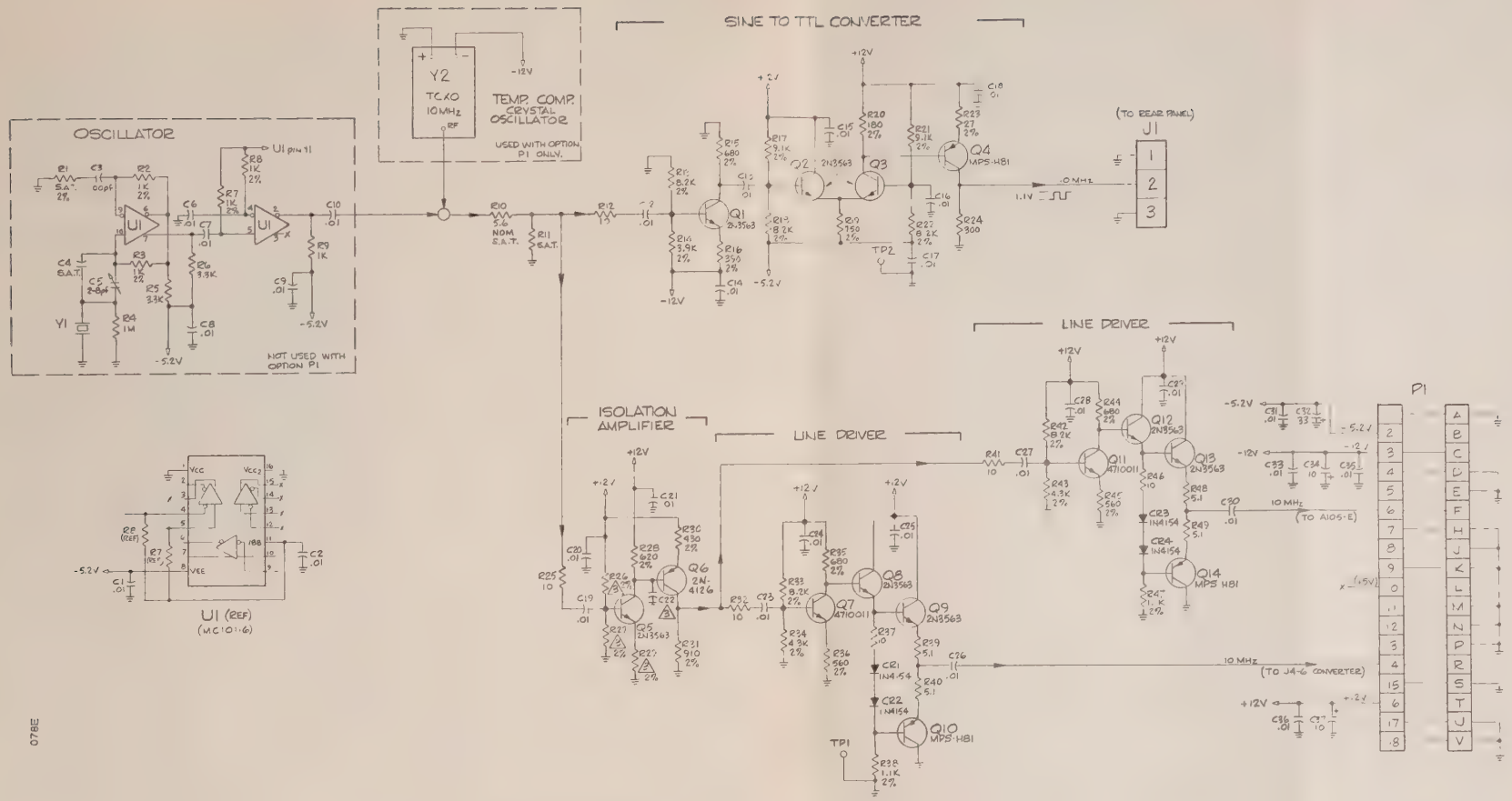


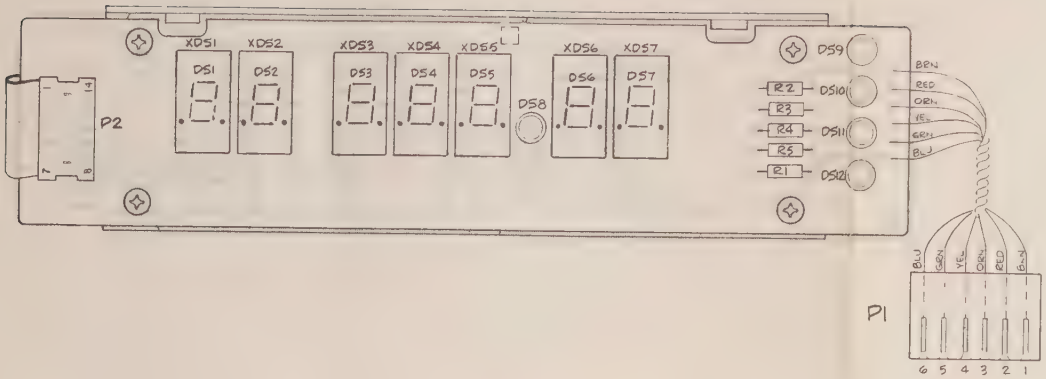
FIGURE 9-10A
COMPONENT LOCATOR
REFERENCE OSCILLATOR BUFFER (A108)



REF DESIG.	STD (EM TEMP OSC)	OPT P1 (TCXO)
R26	11K	9.1K
R27	1.3K	2.2K
R29	100	360
C22	33 pf. S.A.T.	NOT USED

3 COMPONENT VALUES CHANGE WHEN TCXO OPTION P1 IS USED. SEE TABLE FOR CORRECT COMPONENT VALUE FOR EACH APPLICATION.

FIGURE 9-10B
SCHEMATIC DIAGRAM
REFERENCE OSCILLATOR BUFFER (A108)



3080

DISPLAY (A110)

Display board A110 contains seven LED numerical display units mounted side-by-side, grouped into a 2-digit GHz section, and a 5-digit MHz section. The MHz section also contains an LED decimal point between the second and third least-significant-digits (decimal point extinguishes when the two least-significant-digits are blanked by the front panel RESOLUTION switches). All drive signals for the display are obtained from the Count Chain Control.

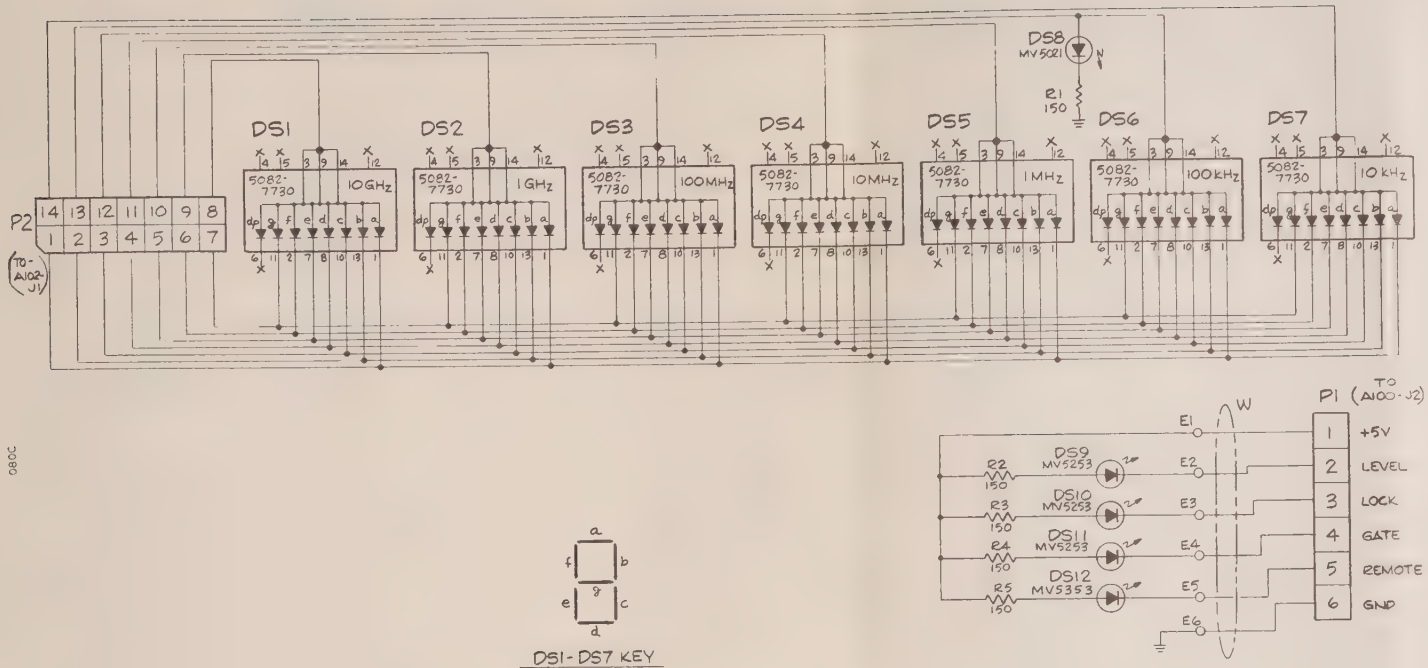
The digit displays are 7-segment LED's, with the anodes of all segments of each digit tied together. When the anode is at a positive voltage, grounding any cathode through its associated resistor illuminates that segment.

In this multiplexed system, the anode supply voltage is applied in pulses (through anode drivers), which are synchronized with the cathode data to determine which segment shall light. The segment drive is applied directly to all display digits. Corresponding cathode segments are all tied together in groups of seven.

The LED digits each use a single transistor driver. The drivers saturate when turned on, applying a voltage almost equal to the supply voltage for the display. This voltage is variable (by A102R35) for display brightness adjustment.

Four display lamps are included on this assembly, which illuminate to indicate GATE operation, input signal LEVEL, LOCK, and REMOTE operation (Option P4).

FIGURE 9-11A
COMPONENT LOCATOR
DISPLAY (A110)



DS1-DS7 KEY

FIGURE 9-11B
SCHEMATIC DIAGRAM
DISPLAY (A110)

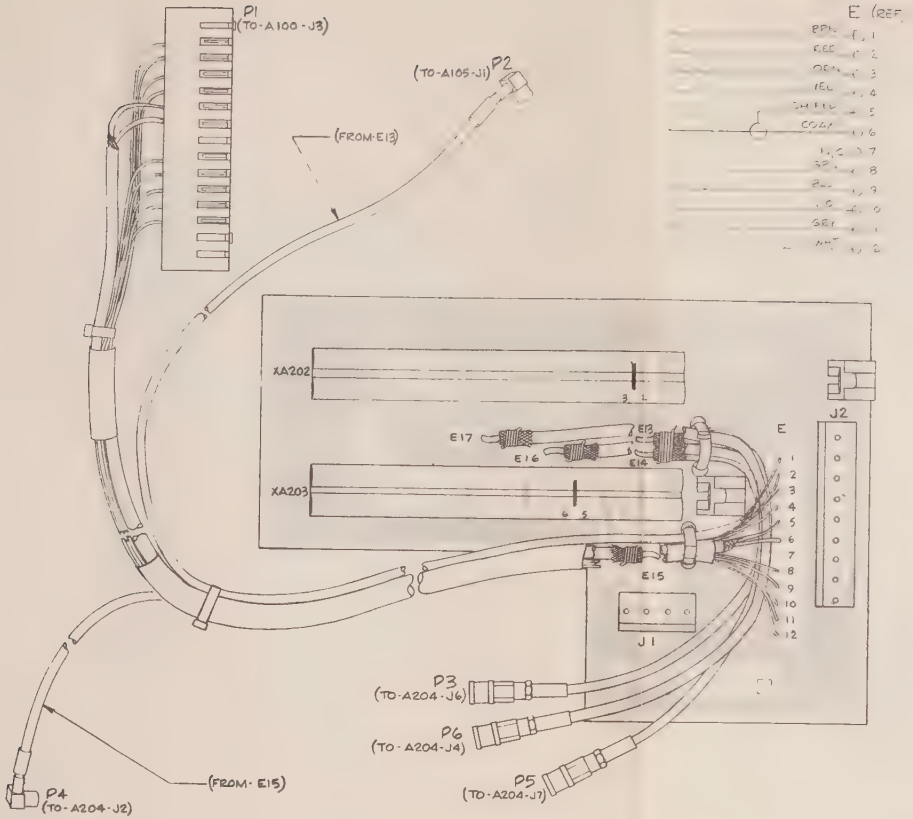
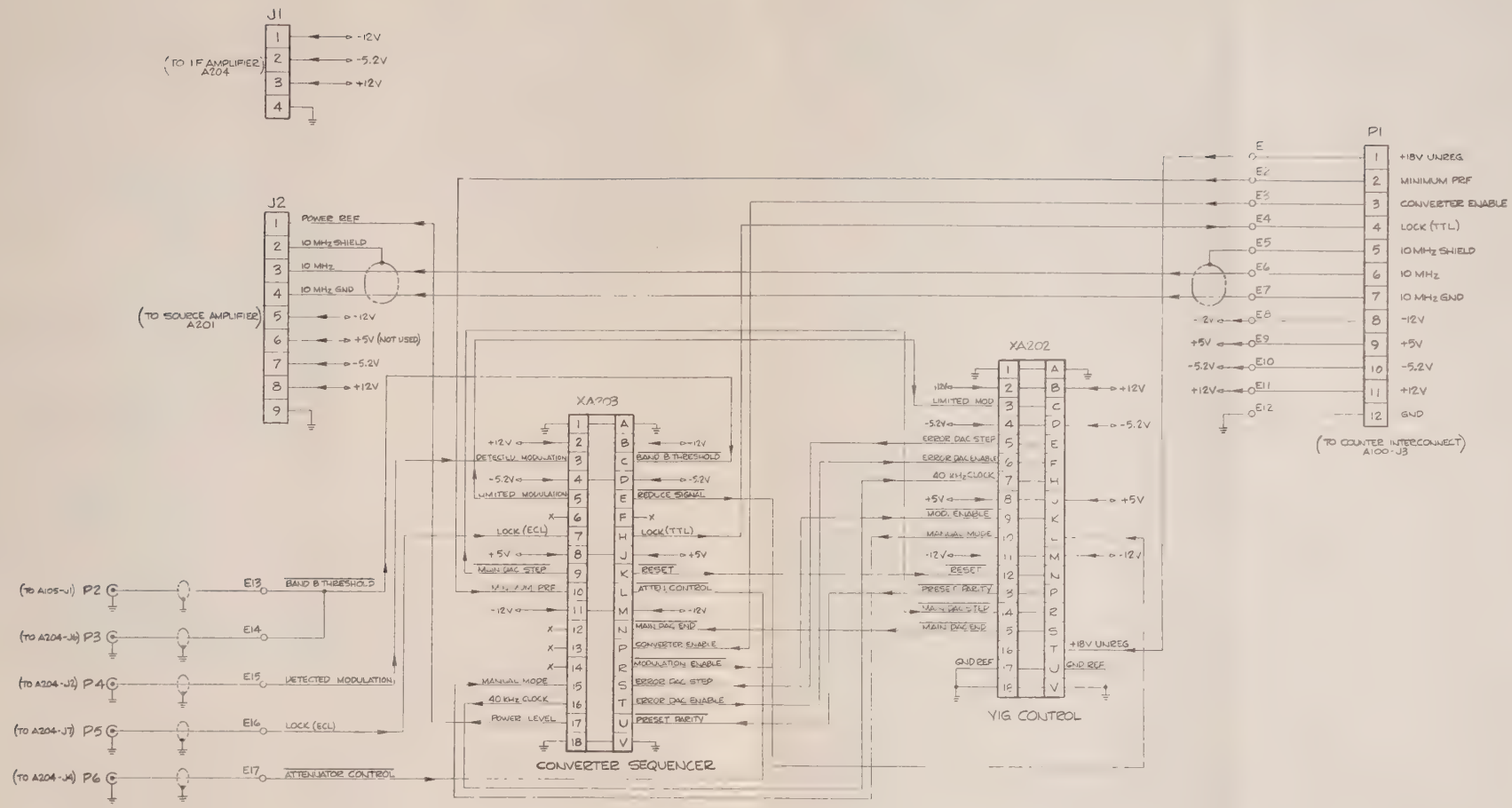
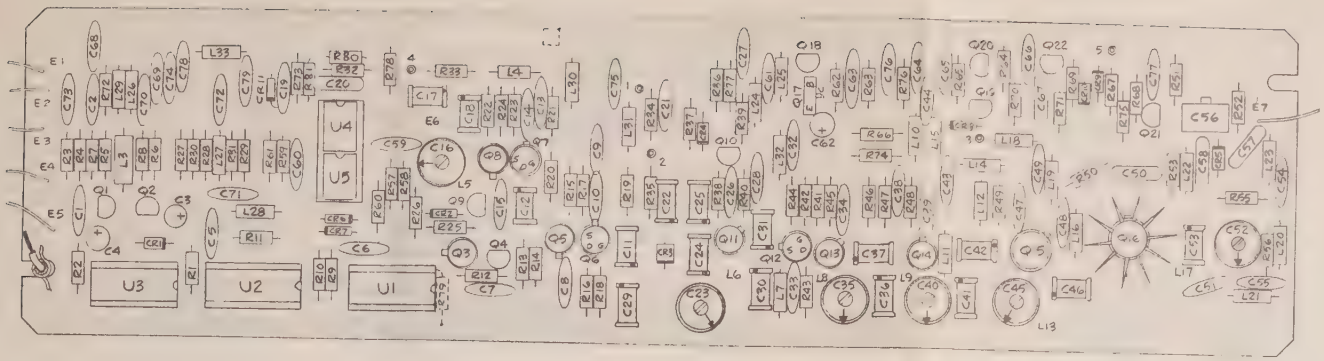


FIGURE 9-12A
COMPONENT LOCATOR
CONVERTER INTERCONNECT (A200)



090A

FIGURE 9-12B
SCHEMATIC DIAGRAM
CONVERTER INTERCONNECT (A200)



091J

SOURCE AMPLIFIER (A201)

General

A source of up to one watt of power at 200 MHz is required to drive the step recovery diode Comb Generator in YIG Assembly A207. The 200 MHz must be both stable and coherent with the master oscillator in the counter. Stability is required to provide an IF spectrum that is dependent only upon the input signal spectrum. Coherence with the master oscillator is required to make counting accuracy dependent only upon the accuracy of the master oscillator.

The requirements of stability and coherence are satisfied by using a phase locked loop to lock a 200 MHz LC oscillator to the 10 MHz time base oscillator. The required output power is generated by a Class C amplifier that contains a leveling loop to set the power output at any desired level from 1 mW to 1.1 W.

Circuit Description

The phase lock loop is a standard second order loop, implemented by using digital phase lock loop components. The 200 MHz LC oscillator is a modified Colpitts circuit with bias stabilization supplied by Q10. The output frequency of the 200 MHz oscillator is divided by 20 in U1 and U2 to produce a 10 MHz square wave. This signal is compared to the processed 10 MHz reference by phase detector U3. Phase error is amplified by active filter U4,and applied to voltage variable capacitor CR3. This holds the 200 MHz oscillator "locked" in phase to the 10 MHz reference signal. C23 sets the open loop center frequency of the oscillator.

The main power amplifier consists of four stages: buffer amplifier Q12 and Q13, linear amplifier Q14, and two Class C stages Q15 and Q16. Output power level is controlled by adjusting the value of the negative voltage supplied by Q17 and Q18 to the linear amplifier and Class C stages.

The power leveling loop operates by sampling the peak value of the output signal with CR5, and comparing this peak value to the Power Reference. The comparison is made by differential amplifier Q19 and Q20, which in turn controls Q17 and Q18.

FIGURE 9-13A
COMPONENT LOCATOR
SOURCE/AMPLIFIER (A201)

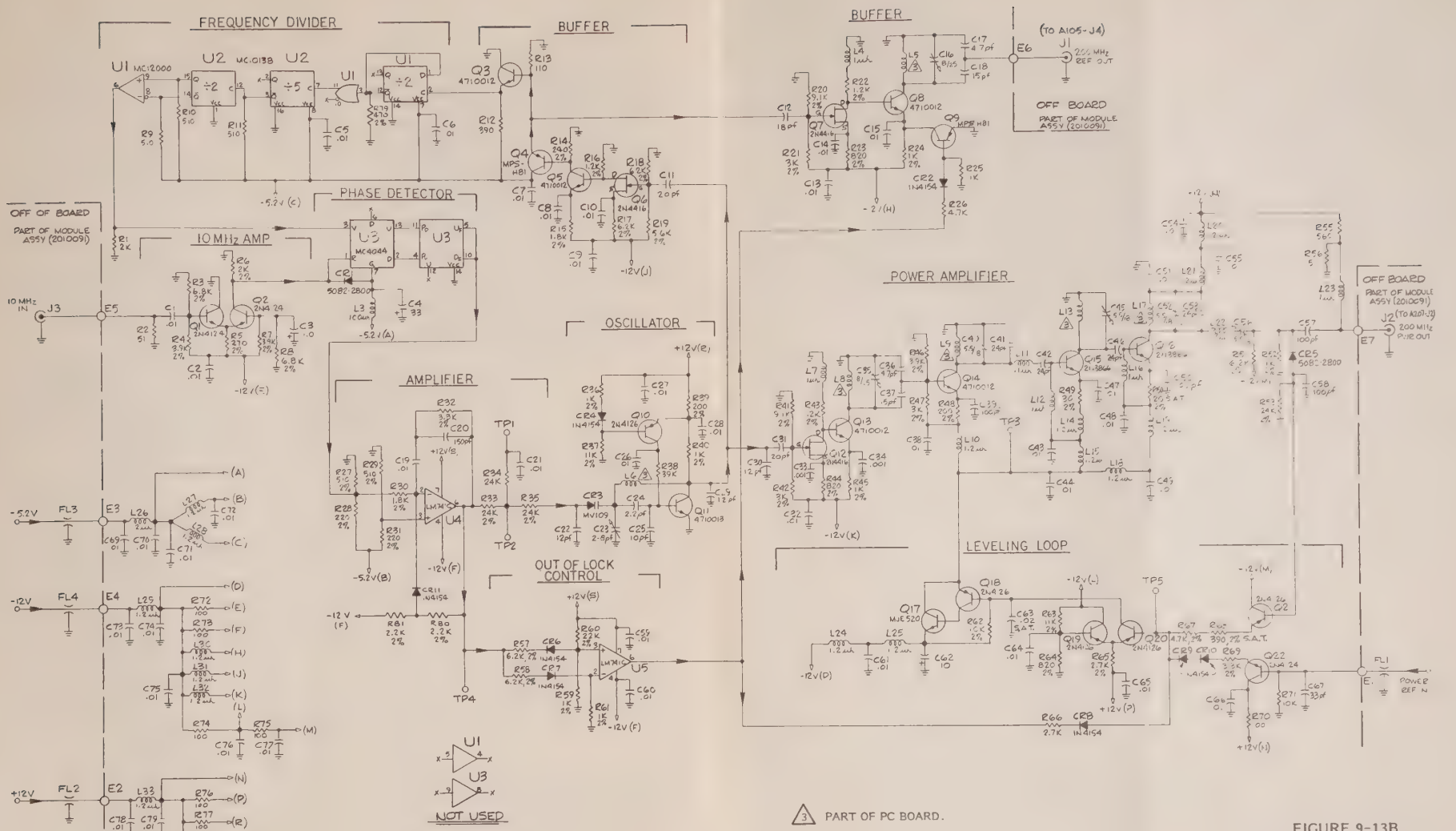
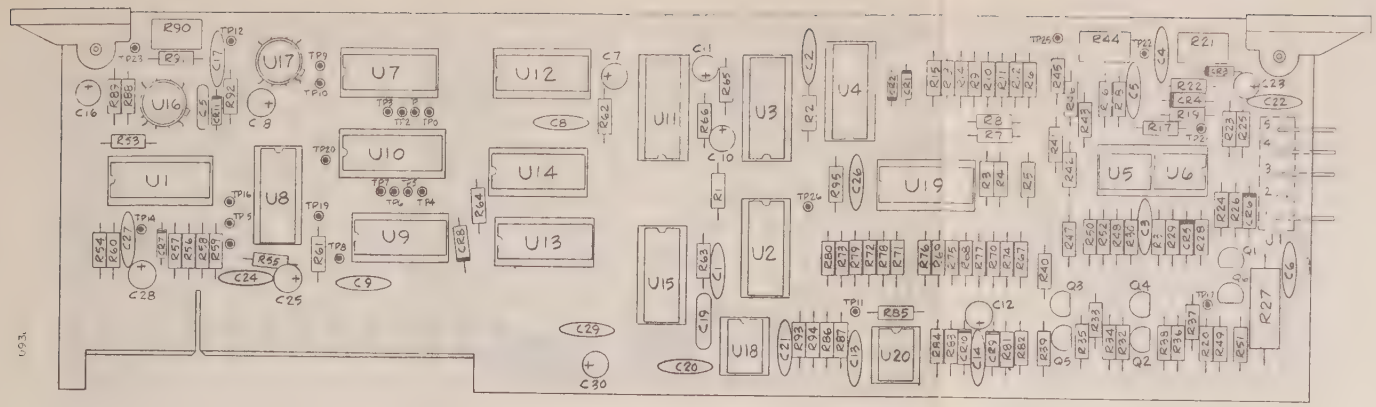


FIGURE 9-13B
SCHEMATIC DIAGRAM
SOURCE/AMPLIFIER (A201)



CONVERTER SEQUENCER (A203)

General

The Converter Sequencer (A203) generates the signals required to step the RF Converter (A2) through its specified frequencies. The board contains a Sequence Generator to generate properly timed start and stop commands for all the required functions. Among the circuits controlled are: the attenuator control and driver circuitry for leveling and switching of the incoming signal, the power level control circuit for controlling the YIG comb power, and Error DAC (digital-to-analog converter) signals controlling the timing of the YIG filter centering circuitry.

Sequence Generator

The basic part of the Converter Sequencer is the Sequence Generator, composed of a binary counter (U8) and a demultiplexer (U10). This circuit generates eight discrete steps, each of which is identified by a low on a corresponding test point (TP0 - TP7).

U8 is driven by a 40 kHz clock (U18) through a network of gates which allow holding the Sequence Generator in any given step until a set of specific conditions signifies that the step is completed. The function of each sequence is shown in Table 9-15A.

Sequence 0 is the state the converter sequence goes to when the converter is disabled. Sequence 0 sets a latch (U12 pin 1) whose output turns off the RF signal by setting the attenuator driver to maximum attenuation, and sending a command to the YIG Control board (A202) to begin the 20 kHz YIG coil modulation. Sequence 0 also sends out a Main DAC step command which steps the Main DAC to the next comb line unless the Converter is being disabled. If so, the disable reset command over-rides the DAC step, and the YIG stops at the bottom (or preset) frequency.

Sequence 1 begins the YIG power leveling cycle. A 1.5 ms one-shot (U11) resets the YIG power DAC (U19) for minimum power, and sets a latch (U15 pins 3,8), whose output inhibits the clock into the Sequence Generator until the power leveling cycle is complete. At the end of the 1.5 ms reset time, the YIG power DAC begins increasing the LO power into the Mixer until either the detected modulation (P1 pin 3) exceeds its threshold, or the LO power reaches its maximum output. At this point the U15 latch is reset which stops the clocking of the power DAC and allows the Sequence Generator to move to the next step.

Sequence 2 begins the YIG coil centering cycle. The centering circuitry is located on the YIG Control board (A202), but the enable time is controlled by the Converter Sequencer.

A 1 ms one-shot is triggered by Sequence 2. Two outputs are taken from the one-shot: the Q output which is used as an Error DAC enable signal to turn on the centering circuitry on the YIG Control board; and $\overline{Q}$ output which is fed back to hold the Sequence Generator in Sequence 3 until the centering process is completed. The end of this process is indicated by a lack of error DAC step pulses. When this occurs, the one-shot times out, and the Sequence Generator is released to go on to Sequence 4.

Sequence 4 is the first step of the sequence in which the input signal is examined. In this step, the latch (U12 pin 1) controlling the input signal is reset; this also turns off the YIG modulation. A second latch (U12 pin 12) is set at the start of Sequence 4. This latch inhibits the sequence during Sequence 5 until a Band B Threshold signal is obtained. This step thus guarantees that at least one input signal has been received during either Sequence 4 or 5.

Sequence 6 is used as a 25 μ sec delay period to provide the necessary time for operation of the Attenuator Control on signals with slow rise times. This is discussed further in the Attenuator Control paragraphs below.

Sequence 7 is the LOCK sensing portion of the sequence. If the signal received during Sequence 4 or 5 resulted in a LOCK command from the IF Processor, then the sequence will remain in Sequence 7, and send a LOCK command to the Control board (A104) in the Basic Counter. If no LOCK was obtained, the Sequencer will continue to Sequence 0, and repeat the sequence with the next comb line.

Attenuator Control

The Attenuator Control circuits perform the function of limiting the variations in input signal amplitude as seen by the Mixer (A205). The ATTENUATOR CONTROL command from the IF Processor (A204) is activated whenever the input signal received by A205 exceeds the minimum signal by at least 7 dB. This command triggers one-shot U3. The output of U3 drives a DAC consisting of a counter (U4), summing resistors (R9 - R14), a summing amplifier (U5), and an inverting amplifier (U6). Each DAC step results in a nominal 0.5 dB increase in attenuator insertion loss. The REDUCE SIGNAL indicator on the front panel is activated when the DAC reaches its 32nd step.

The DAC acts as a sample and hold circuit for attenuation level. As long as there is insufficient attenuation, the ATTENUATOR CONTROL command will cause the attenuation to increase 0.5 dB for each input pulse. On long pulses or CW signals, U3 will retrigger as long as the ATTENUATOR CONTROL command remains active.

In addition to increasing attenuator insertion loss, the ATTENUATOR CONTROL command forces the Sequence Generator to Sequence 3 by activating the preset strobe line of U8. Since the RF switch remains open, and the YIG modulation is not enabled, the Sequencer then moves on through Sequence 4 and 5, and again waits for Band B Threshold. The result is that the Sequencer cannot go on to Sequence 6 until the attenuator has reduced the input signal sufficiently.

Attenuator Driver

The output of U6 is a voltage corresponding to the desired attenuation. This signal is converted into two related currents by the Attenuator Driver. These currents: I_{total} and I_{series}, determine both the attenuation and the input VSWR of the PIN Diode Attenuator (part of A206).

Series current is generated by the network of U5 and Q6. R53 is the sense resistor for the current source. The nonlinear current output versus input level is achieved with a double breakpoint shaping network -- Q2 and Q3 form one breakpoint, while Q4 and Q5 form the other. Variable resistor R47 sets the series current, and optimizes VSWR, at high attenuation levels.

Total current is the sum of series current and shunt current. The shunt current waveform is shaped by diode network CR2, CR3, and their associated resistors. Variable resistor R23 is used to adjust the ratio between series and shunt currents at moderate attenuation levels. U6 and current booster Q1, combine series and shunt networks to produce the total current output.

Power Level Control

During Sequence 1, the YIG comb level is set. This function is accomplished by varying the POWER REFERENCE level into the Source/Amplifier (A201). This in turn varies the 200 MHz power into the YIG/Comb Generator (A207). The comb line output is detected by the Mixer, and sensed by the Threshold Detector U17. Variable resistor R64 sets the threshold level.

Operation of the Power Level Control begins at the end of the 1.5 ms period of U11. Clock pulses from U18 are then allowed to step the Power Level DAC (U19, R74 thru R80). When the comb output exceeds the threshold, U17 triggers, resetting the latch (U15 pin 10), inhibiting the clock input to the DAC and ending the sequence. If the DAC reaches maximum output, the same result is obtained.

FIGURE 9-15A
COMPONENT LOCATOR
CONVERTER SEQUENCER (A203)

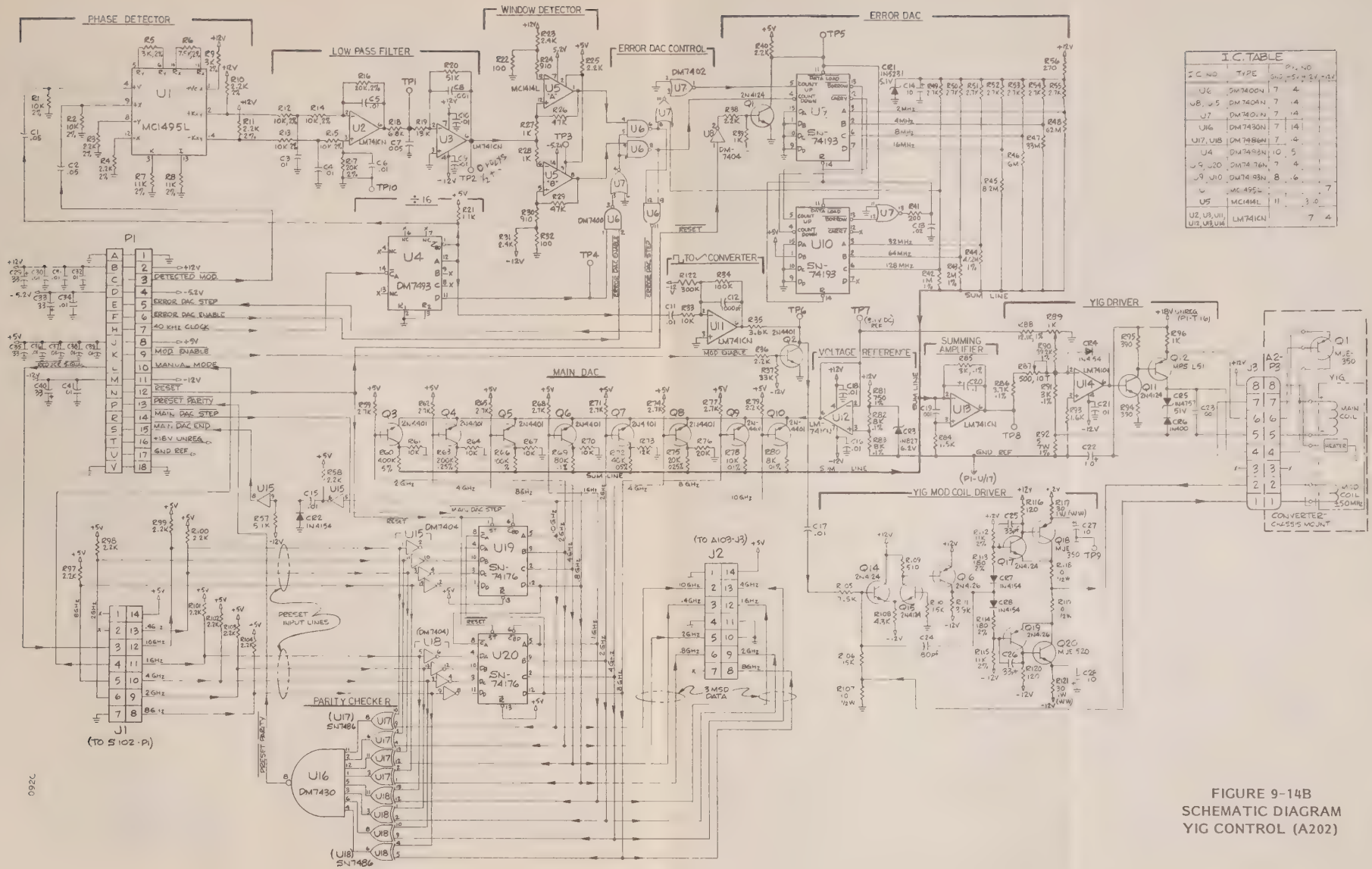
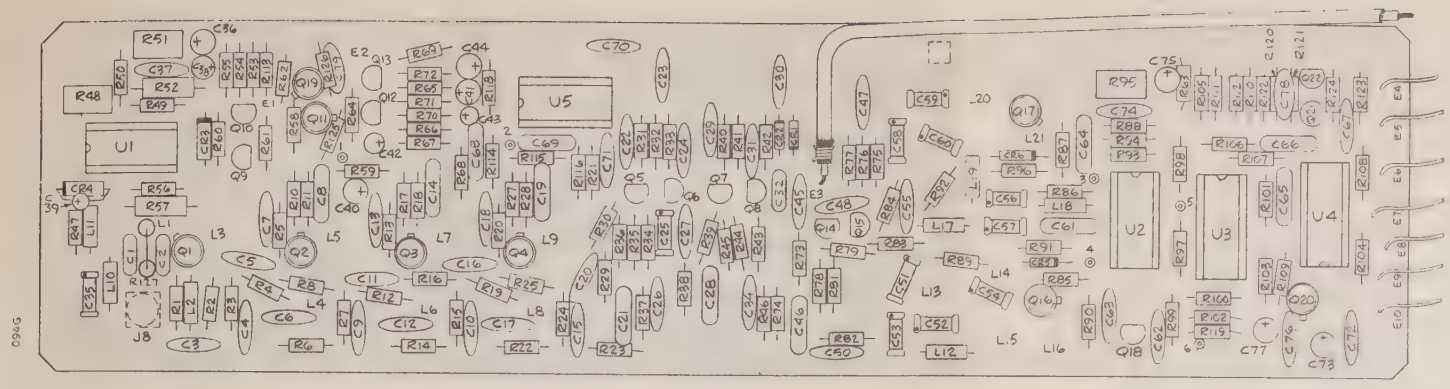


FIGURE 9-14B
SCHEMATIC DIAGRAM
YIG CONTROL (A202)



IF PROCESSOR (A204)

IF Processor A204 receives its input from the Mixer (A205). It separates the Mixer output into IF and Video components, and processes the components to produce several outputs. The IF signal is amplified and limited for counting. The Video signal is used to produce the SIGNAL THRESHOLD, DETECTED MODULATION, and ATTENUATOR CONTROL signals directly. SIGNAL THRESHOLD is combined with the external INHIBIT INPUT to produce BAND B THRESHOLD. This signal, together with the IF signal, is used to determine LOCK.

IF Amplifier

The IF component of the Mixer output is amplified in a six stage amplifier having an overall gain of 50 dB, and a bandwidth covering 100 MHz to 375 MHz. Stage 1 (Q1) is a common emitter amplifier with shunt feedback (R2). L2 and L3 provide high frequency shaping of the response. Stages 2, 3, and 4 (Q2-4) are similar to Stage 1. Gain is set by the emitter resistors. High frequency gain shaping is provided by the emitter RC network (R11,C8), and the collector inductor (L5).

Stages 5 and 6 are limiting amplifiers, each consisting of an amplifier (Q5,Q7) and an emitter follower (Q6,Q8). Each stage has a nominal gain of 10 dB, determined by the input and feedback resistors (R30,34,35). Capacitive bypassing (C25) is used for high frequency gain shaping. Diodes (CR1,2) limit the final output still further.

Video Circuits

The Video output of the Mixer, representing the detected envelope of a microwave signal, is amplified by U1. R48 sets the voltage gain (nominally 100), while R51 nulls out any offset between the differential outputs at U1 pins 7 and 8.

Outputs of U1 are applied to a high speed differential amplifier (Q9,10). Positive feedback from R61 converts this circuit to a Schmitt trigger. Q11 is an emitter follower used to drive the high speed ECL gates. The same outputs of U1 also differentially drive comparator U5 which forms the Attenuator Threshold Detector. Resistive biasing and feedback (R114-116,118) set the trigger level of this circuit approximately 7dB above the Signal Threshold Detector level.

The remaining Video circuit is the 20 kHz amplifier consisting of Q12 and Q13. This circuit provides an additional voltage gain of 100 at frequencies near 20 kHz, and is used to detect the modulated comb lines during YIG leveling and centering operations.

In-Band Detector

The In-Band Detector determines whether or not an IF signal exists within the correct frequency range and at sufficient level to obtain LOCK. The correct frequency range is the region from 100 MHz to 325 MHz. After LOCK, the upper end of this region is extended to 350 MHz.

A portion of the IF signal is coupled into an additional limiter section (Q14,15) similar to the limiters in the IF Amplifier section. The output then drives two filter networks in parallel. The output of each network is detected (CR5,-CR6), and compared in U2. Since input signal amplitude is held constant, the detected signals are determined entirely by the filter characteristics. One of the filter networks consists of a 100 MHz high-pass section (C51-53,-L12) in series with a 325 MHz low-pass section (L13-16,-C54), thus forming a band-pass filter from 100-300 MHz.

The second network consists of a 100 MHz low-pass section (L17-19,C57) in parallel with a 325 MHz high-pass section (C58-60,L20,L21), forming a band reject filter from 100-325 MHz.

By comparing the outputs of these two networks in U2, a determination of the IF frequency is made. R95 is used to precisely set the crossover frequency. After LOCK is obtained, Q16 and Q17 are turned on, shorting out L16 and L21, and increasing the crossover point from 325 MHz to 350 MHz.

LOCK Logic

The LOCK logic determines whether or not the proper conditions exist to consider the Converter locked. The condition to obtain LOCK is that an In-Band signal (from U2 pin 9) appears within 70 nanoseconds of the appearance of BAND B THRESHOLD (at Q11 collector). Once this condition is met, the LOCK command is latched, and remains active until a loss-of-lock condition is obtained — that is: an In-Band signal is not received within 70 nanoseconds of BAND B THRESHOLD.

BAND B THRESHOLD is generated by combining CONVERTER THRESHOLD (from Q11) with the external INHIBIT INPUT. The INHIBIT INPUT is buffered by Q21 and Q22. The two signals are combined at pins 12 and 13 of OR gate U3.

The LOCK latch consists of two gates of U4 with the output at U4 pin 14. The set input to this latch (U4 pin 5) is driven by a 3-input NOR gate (U4). The latch is set when all three inputs of the NOR gate are simultaneously low. R107 and C66 provide a 70 nanasecond delayed BAND B THRESHOLD to one input, while the inverted signal without a delay is applied to the second input. An inverted IN-BAND signal is applied to the third input. Thus a 70 nanosecond interval exists after BAND B THRESHOLD occurs, during which the LOCK latch may be set. The reset input to the latch is also a 3-input gate (U3), connected so IN-BAND must occur within 70 nanoseconds or the latch will be reset. If IN-BAND drops out while BAND B THRESHOLD remains (at any point in time after the 70 nanosecond interval), the latch is immediately reset.

FIGURE 9-16A
COMPONENT LOCATOR
IF PROCESSOR (A204)

SEQUENCE	FUNCTIONS	DURATION
0	1. Attenuator to max attenuation. 2. YIG Modulation enabled. 3. Main DAC step. 4. Reset state.	25 μs unless held by RESET.
1	1. YIG comb leveling cycle.	1.5 - 4.7 msec.
2	1. Initiate YIG centering cycle.	25 μ seconds.
3	1. YIG centering cycle.	1 - 10 mseconds.
4	1. Attenuator to normal control. 2. Modulation off. 3. Initiate wait for Band B Threshold.	25 μ seconds.
5	1. Wait for Band B Threshold.	Depends upon PRF.
6	1. 25 μ second delay.	25 μ seconds.
7	1. LOCK sensing sequence.	25 μ sec if no LOCK.

TABLE 9-15A. CONVERTER SEQUENCE FUNCTIONS

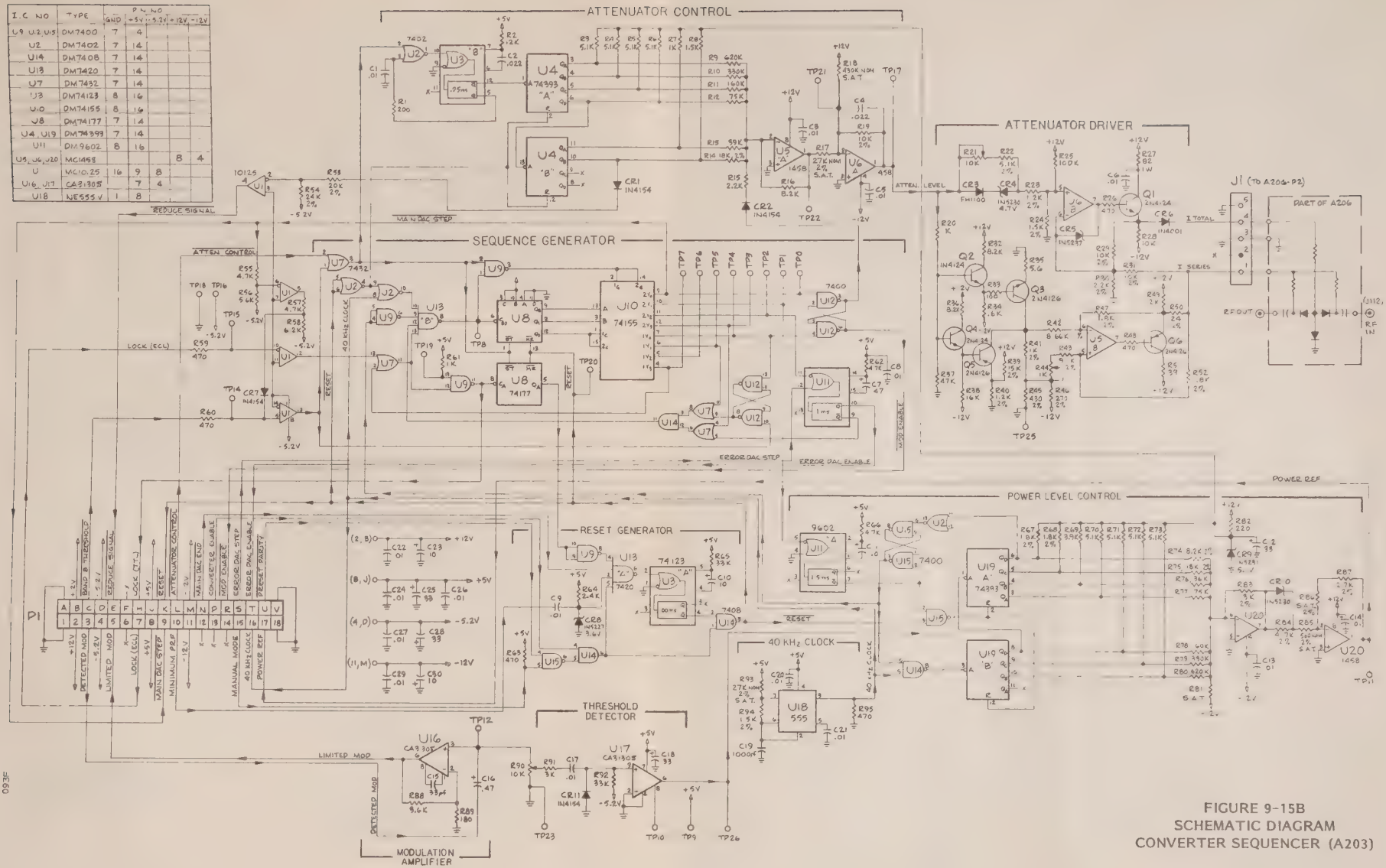


FIGURE 9-15B
SCHEMATIC DIAGRAM
CONVERTER SEQUENCER (A203)

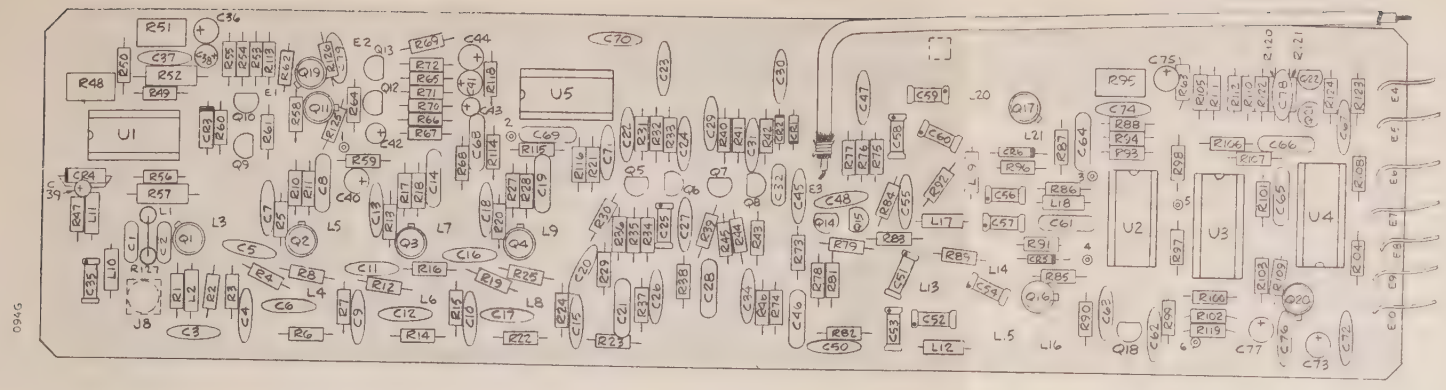


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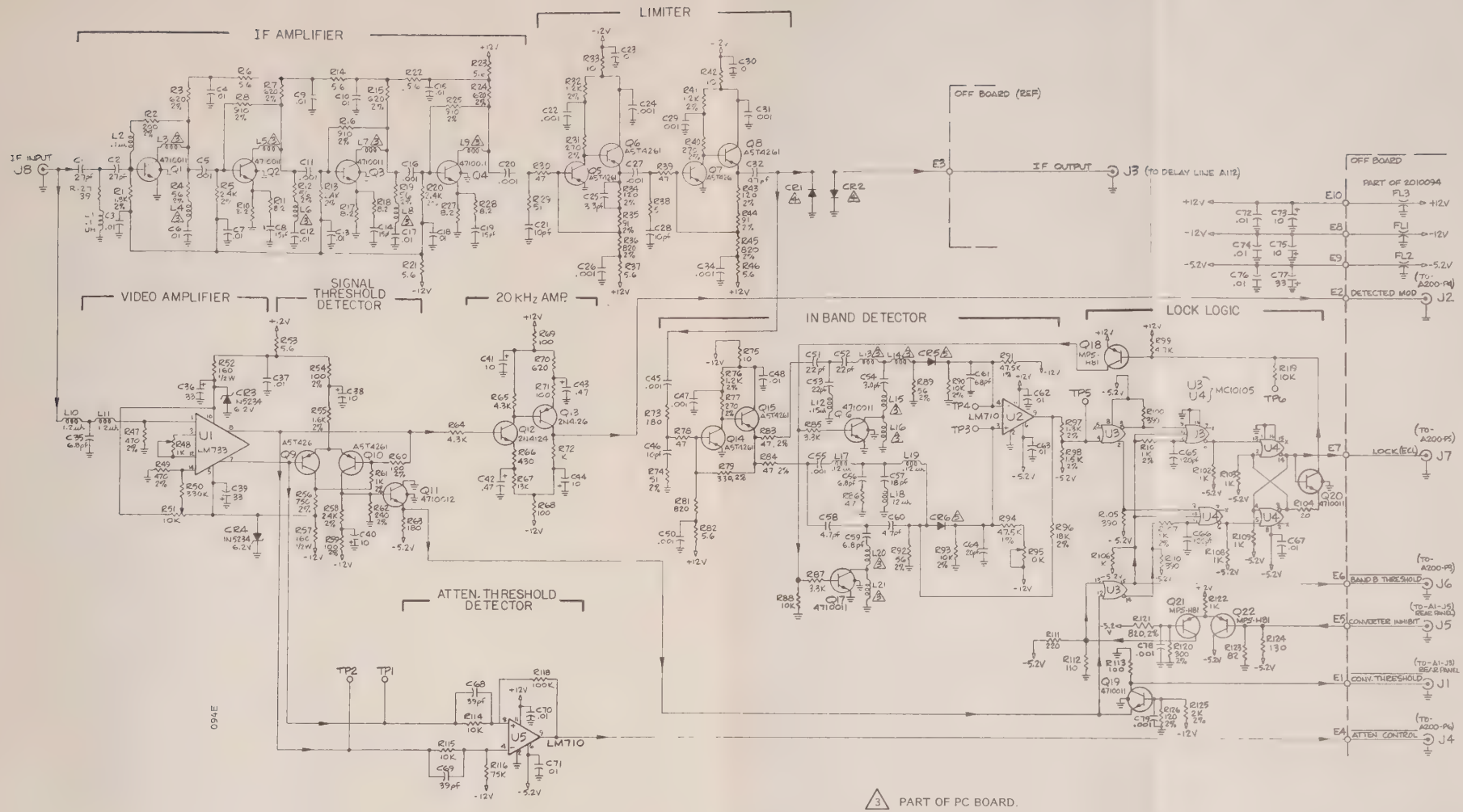
FIGURE 9-16A
COMPONENT LOCATOR
IF PROCESSOR (A204)



3 PART OF PC BOARD.

4 SEE PARTS LIST.

5 MATCHED PAIR.

FIGURE 9-16B
SCHEMATIC DIAGRAM
IF PROCESSOR (A204)

SECTION O

OPTIONS

O-1. This section provides schematic diagrams, circuit descriptions and component locators, for options available for use with the 451 Microwave Pulse Counter.

O-2. OPTION P1 - TCXO

O-3. For a description of the use of this option, refer to paragraphs 3-29 through 3-38, and paragraph 4-28. The TCXO is installed on Reference Oscillator Buffer board A108 in place of the standard RTO. See pages 9-20 and 9-21 for schematic, board layout, and circuit description.

O-4. OPTION P2 - PRESCALER

O-5. This option extends the frequency range of the 451 down to 300 MHz to 950 MHz. See pages O-2 and O-3 for schematic, board layout, and circuit description.

O-6. OPTION P3 - REAR PANEL INPUTS

O-7. For this option, the Converter is switched end-for-end, with the Band B input connector projecting through the existing opening in the rear panel, and with certain cables re-routed and changed in length.

O-8. TO FIELD CHANGE BAND B TO REAR INPUT

a. Disconnect power cord, and remove both top and bottom covers from the counter.

b. Unplug all cables which connect Converter to Basic Counter. Note cable routing and connections.

c. Unscrew Converter tray retaining screws (from bottom of Counter).

d. Lift rear of Converter tray, and carefully slide Converter out of counter enclosure.

e. Turn Converter end-for-end, and insert the Band B connector through the hole in the rear panel labeled 925 MHz - 18 GHz.

f. Lower Converter carefully into counter enclosure, taking precautions not to pinch any wires or cables.

g. Install screws which hold Converter in enclosure, and reconnect cables unplugged in step b above.

h. Perform Incoming Operational Check described in Section 2 - Installation.

i. Apply a signal to the Band B input connector within the correct frequency and power limits, checking for proper operation of the Converter. Specifications remain identical to those for front panel operation.

O-9. TO FIELD CHANGE BANDS A AND B TO REAR INPUT

a. Disconnect power cord, and remove both top and bottom covers from the counter.

b. Unplug all cables which connect Converter to Basic Counter. Note cable routing and connections.

c. Unscrew Converter tray retaining screws (from bottom of Counter).

d. Lift rear of Converter tray, and carefully slide Converter out of counter enclosure.

e. Turn Converter end-for-end, and insert the Band B connector through the hole in the rear panel labeled 925 MHz - 18 GHz.

f. Lower Converter carefully into counter enclosure, taking precautions not to snag or pinch any wires or cables.

g. Install screws which hold Converter in enclosure.

h. Locate Double Delay Line Assembly A116. Note that three cables exit from under one end of the cover, and one cable (to A204J3) exits from under the other end of the cover. Loosen, but do not remove the screws holding the Delay Line cover in place. Re-route the cable to A204J3 so it exits from the same end as the remaining three cables. Tighten the Delay Line cover screws.

i. All three plug-in cables to the Prescaler PC board (A109) must be replaced with those of a different length as follows: Replace short W30 cable (A109J1 - A1J111) with long W30 cable (with BNC connector mounted on rear panel); replace short W31 cable (A109J5 - A204J1) with long W31 cable; replace long W32 cable (A109J4 - A204J5) with short W32 cable.

j. Reconnect all cables unplugged in steps b and i.

k. Perform Incoming Operational Check described in Section 2 - Installation.

l. Apply a signal to the Band B input connector within the correct frequency and power limits, checking for proper operation of the Converter. Specifications remain identical to those for front panel input.

m. Apply a signal to the Band A input connector within the correct frequency and power limits, checking for proper operation of the Prescaler. Specifications remain identical to those for front panel input.

O-10. OPTION P4 - BCD OUTPUT/REMOTE PROGRAMMING

O-11. BCD output, remote programming, and YIG preset, are the three basic functions provided by this option. Circuitry to accomplish these functions is contained on PC board A111, with connections made through rear panel REMOTE INPUT/OUTPUT connector A1J7. All inputs and outputs are TTL compatible. Each basic function will be described separately, with A1J7 pin assignments and functions shown in Table O-1. (Recommended mating connector for A1J7: Amphenol 57-30500, 50 pin male — EIP Part No. 2640003.) See pages O-4 and O-5 for schematic and layout.

O-12. BCD OUTPUTS

O-13. BCD formated outputs to A1J7 correspond to the applied signal input frequency. A PRINT command output signal indicates the presence of valid data, while an INHIBIT input prevents the data from being altered. Both PRINT and INHIBIT signals are active high.

O-14. BCD information from High Frequency board A106 enters A111 via J5 and J6. U1 through U5 buffer the information and supply it via P1 to A1J7.

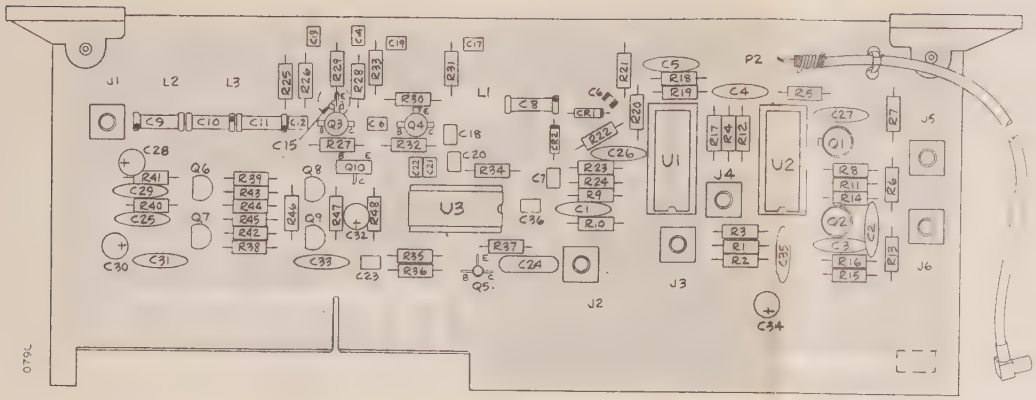
O-15. YIG PRESET

O-16. YIG preset information is supplied to the counter from two sources, depending upon the status of the Local/$\overline{\text{Remote}}$ line. In the Local mode, preset information comes from the front panel thumbwheel and MAN SELECT/AUTO SWEEP switches. In the $\overline{\text{Remote}}$ mode, preset information is obtained via A1J7, and controlled by the status of the Conv Man/$\overline{\text{Auto}}$ line. Increments of 200 MHz may be programmed using the standard 1-2-4-8 BCD code.

O-17. REMOTE PROGRAMMING

O-18. Except for POWER ON/OFF and SAMPLE RATE, all front panel switch functions can be remotely controlled. Additional remotely programmable functions which are in continuous operation and are unaffected by the status of the Local/$\overline{\text{Remote}}$ line, are: $\overline{\text{Fast Cycle}}$, Cycle Counter, and Pulse Reset. $\overline{\text{Fast Cycle}}$ bypasses the display delay generator and over-rides the SAMPLE RATE control. Cycle Counter is a capacitive-coupled input signal to reset the Basic Counter and initiate a new reading. Pulse Reset triggers a one-shot to reset the Counter and Converter.

O-19. U6 through U9 are quad 2-input multiplexers which are selected by the Local/$\overline{\text{Remote}}$ line to provide data from either the front panel switches (Local mode), or from the rear panel connector A1J7 ($\overline{\text{Remote}}$ mode). R6-R9 and U3 act as an input buffer for the INHIBIT line, thus allowing operation from 0 to +50 volts. CR1 and CR2 act as clamping diodes.



PRESCALER (A109)

General

This option permits the measurement of pulse modulated signals that lie within the frequency range of 300 MHz to 950 MHz, and with pulse widths as narrow as 100 nsec.

The Prescaler divides the input signal frequency by four before applying it to the High Frequency board (A106). Simultaneously, the gate time is extended by a factor of four, to allow display of the true input frequency.

Circuit Description

Input RF power is amplified in broadband limiting amplifiers Q3 and Q4, and applied to U3 which divides the frequency by four. Emitter follower Q5 provides sufficient drive current for 50 ohms lines.

The output of Q3 and Q4 is also applied to a threshold trigger circuit. The envelope is first detected by C6, CR1, and CR2, before driving Schmitt trigger U1A. Threshold of the Schmitt circuit is adjusted to trigger only at signal levels that are sufficiently large enough to permit reliable counting in the divide by four circuitry of U3.

Power for U3 is switched on or off by the circuitry associated with Q6 - Q10. When the Band A Select line goes to a TTL high, differential amplifier Q6/7 saturates Q9 and allows the base of Q8 to become biased at approximately -7.4 volts. Q8 and Q10 are emitter followers that supply the -7.4 volts at approximately 60 ma to U3.

The remainder of the circuitry is interface switching logic to provide the indicated control signals. When the Band A Select line goes to a TTL high, U2A is enabled and passes the Band A signal threshold to the SIGNAL THRESHOLD output connector on the rear panel of the counter. Conversely, when the line is a TTL low, the Converter threshold signal is passed through U2B to the connector.

If the INHIBIT INPUT is either open, an ECL low (-1.7 V), or -1 volt from a 50 ohm source, U1C enables U2C allowing passage of the threshold trigger to the Gate Generator.

FIGURE P2-A
COMPONENT LOCATOR
PRESCALER (A109)
OPTION P2

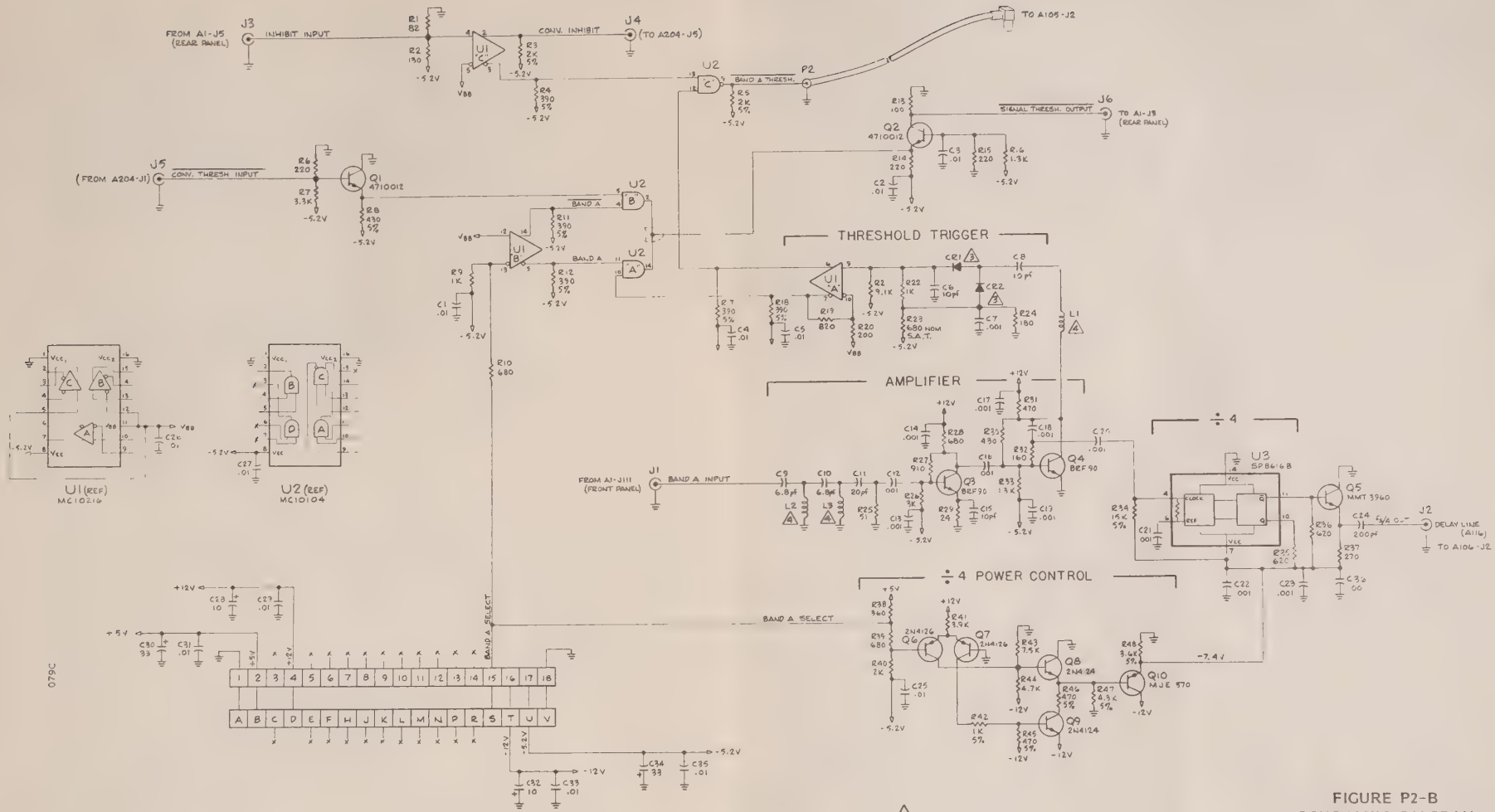


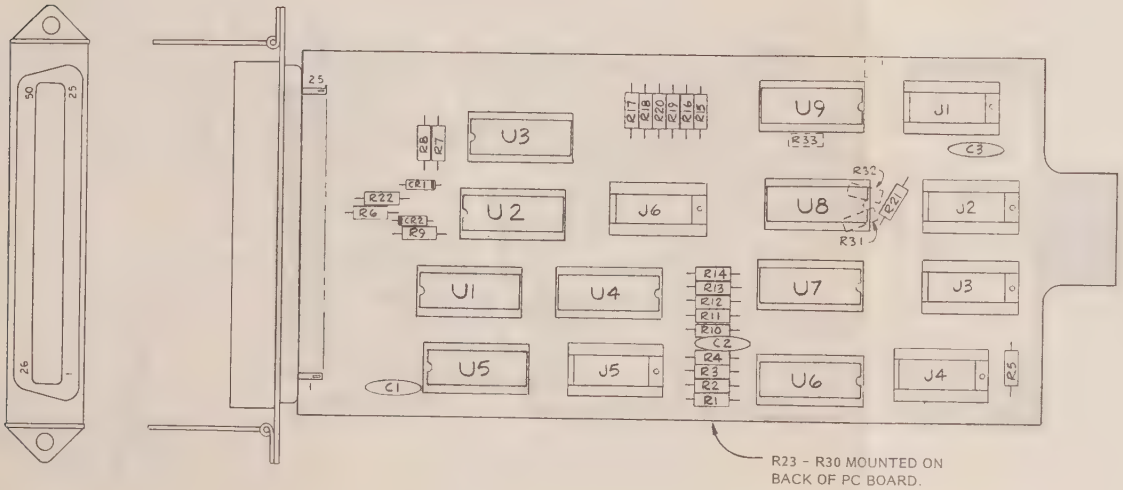
FIGURE P2-B
SCHEMATIC DIAGRAM
PRESCALER (A109)
OPTION P2

Pin No.	Function	Pin No	Function	Pin No	Function
1	10^4 A	18	$\overline{\text{Preset 1 GHz}}$	35	10^8 D
2	10^4 B	19	$\overline{\text{Preset 0.4 GHz}}$	36	10^9 C
3	10^5 A	20	Conv. Man/$\overline{\text{Auto}}$	37	10^9 D
4	10^5 B	21	Cycle Counter	38	10^{10} C
5	10^6 A	22	$\overline{\text{Fast Cycle}}$	39	+5 Vdc Ref
6	10^6 B	23	$\overline{\text{1 MHz}}$ Resolution	40	Print Command
7	10^7 A	24	$\overline{\text{Band A}}$	41	$\overline{\text{Preset 8 GHz}}$
8	10^7 B	25	Local/$\overline{\text{Remote}}$	42	$\overline{\text{Preset 2 GHz}}$
9	10^8 A	26	10^4 C	43	$\overline{\text{Preset 0.8 GHz}}$
10	10^8 B	27	10^4 D	44	$\overline{\text{Preset 0.2 GHz}}$
11	10^9 A	28	10^5 C	45	$\overline{\text{Hold}}$
12	10^9 B	29	10^5 D	46	$\overline{\text{Test}}$
13	10^{10} A	30	10^6 C	47	$\overline{\text{Reset}}$
14	10^{10} B	31	10^6 D	48	$\overline{\text{100 kHz}}$ Resolution
15	Inhibit	32	10^7 C	49	Pulse Reset
16	$\overline{\text{Preset 10 GHz}}$	33	10^7 D	50	Ground
17	$\overline{\text{Preset 4 GHz}}$	34	10^8 C		

NOTES FOR TABLE O-1:

1 The 10^0 bit is the least significant bit, and corresponds to the 10 kHz output. A, B, C, and D are the 1, 2, 4, and 8 bits of each BCD digit.
2 "Barred" commands ($\overline{\text{Hold}}$, $\overline{\text{Test}}$, etc.) are active low.
3 The command "$\overline{\text{Hold}}$" retains the reading until manually reset. "$\overline{\text{Test}}$" provides the same information as the front panel **TEST** switch. "$\overline{\text{Reset}}$" over-rides the **SAMPLE RATE/HOLD** control, resets the display to zero, and initiates a new reading. "$\overline{\text{100 kHz}}$" and "$\overline{\text{1 MHz}}$" set the resolution in the same manner as the front panel **RESOLUTION** switches. "$\overline{\text{Band A}}$" places the counter in the Band A (Prescaler) range: 300 MHz - 950 MHz.

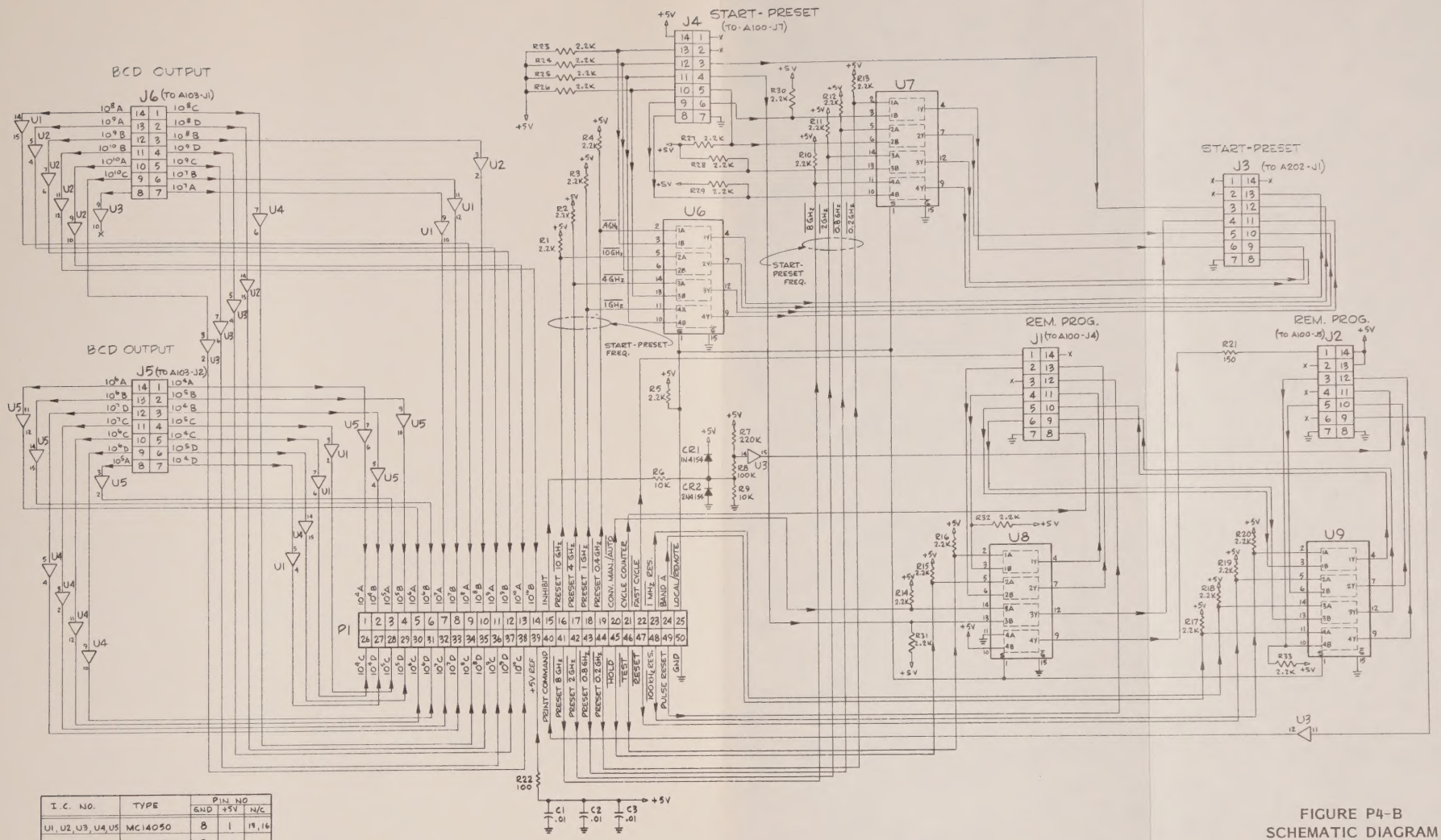
TABLE O-1
PIN ASSIGNMENTS
BCD OUTPUT/REMOTE
PROGRAMMING CONNECTOR
(A1J7)



082C

REFER TO PAGE O-1 FOR CIRCUIT DESCRIPTION

FIGURE P4-A
COMPONENT LOCATOR
BCD OUTPUT/REMOTE
PROGRAMMING (A111)
OPTION P4



I.C. NO.	TYPE	PIN NO		
		GND	+5V	N/C
U1, U2, U3, U4, U5	MC14050	8	1	13, 16
U6, U7, U8, U9	DM74157	8	16	

FIGURE P4-B
SCHEMATIC DIAGRAM
BCD OUTPUT/REMOTE
PROGRAMMING (A111)
OPTION P4

082B

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